



North Carolina Department of Public Instruction

INSTRUCTIONAL SUPPORT TOOLS

FOR ACHIEVING NEW STANDARDS

NC Math 3 Mathematics • Unpacked Contents

For the new Standard Course of Study that will be effective in all North Carolina schools in the 2017-18 School Year.

This document is designed to help North Carolina educators teach the NC Math 3 Standard Course of Study. NCDPI staff are continually updating and improving these tools to better serve teachers and districts.

What is the purpose of this document?

The purpose of this document is to increase student achievement by ensuring educators understand the expectations of the new standards. This document may also be used to facilitate discussion among teachers and curriculum staff and to encourage coherence in the sequence, pacing, and units of study for grade-level curricula. This document, along with on-going professional development, is one of many resources used to understand and teach the NC SCOS.

What is in the document?

This document includes a detailed clarification of each standard in the grade level along with a *sample* of questions or directions that may be used during the instructional sequence to determine whether students are meeting the learning objective outlined by the standard. These items are included to support classroom instruction and are not intended to reflect summative assessment items. The examples included may not fully address the scope of the standard. The document also includes a table of contents of the standards organized by domain with hyperlinks to assist in navigating the electronic version of this instructional support tool.

How do I send Feedback?

Link for: [Feedback for NC's Math Resource for Instruction](#) We will use your input to refine our unpacking of the standards. Thank You!

Just want the standards alone?

Link for: [NC Mathematics Standards](#)

North Carolina Math 3 Standards

Number

The complex number system

Use complex numbers in polynomial identities and equations

[NC.M3.N-CN.9](#)

Algebra

Overview

Seeing structure in expressions

Interpret the structure of expressions

[NC.M3.A-SSE.1a](#)

[NC.M3.A-SSE.1b](#)

[NC.M3.A-SSE.2](#)

Write expressions in equivalent form to solve problems

[NC.M3.A-SSE.3c](#)

Perform arithmetic operations on polynomials

Understand the relationship between zeros and the factors of polynomials

[NC.M3.A-APR.2](#)

[NC.M3.A-APR.3](#)

Rewrite rational expressions

[NC.M3.A-APR.6](#)

[NC.M3.A-APR.7a](#)

[NC.M3.A-APR.7b](#)

Creating equations

Create equations that describe numbers or relationships

[NC.M3.A-CED.1](#)

[NC.M3.A-CED.2](#)

[NC.M3.A-CED.3](#)

Reasoning with equations and inequalities

Understand solving equations as a process of reasoning and explain the reasoning

[NC.M3.A-REI.1](#)

[NC.M3.A-REI.2](#)

Represent and solve equations and inequalities graphically

[NC.M3.A-REI.11](#)

Functions

Overview

Interpreting functions

Understand the concept of a function and use function notation

[NC.M3.F-IF.1](#)

[NC.M3.F-IF.2](#)

Interpret functions that arise in applications in terms of a context

[NC.M3.F-IF.4](#)

Analyze functions using different representations

[NC.M3.F-IF.7](#)

[NC.M3.F-IF.9](#)

Building functions

Build a function that models a relationship between two quantities

[NC.M3.F-BF.1a](#)

[NC.M3.F-BF.1b](#)

Build new functions from existing functions

[NC.M3.F-BF.3](#)

[NC.M3.F-BF.4a](#)

[NC.M3.F-BF.4b](#)

[NC.M3.F-BF.4c](#)

Linear, Quadratic and Exponential Models

Construct and compare linear and exponential models to solve problems

[NC.M3.F-LE.3](#)

[NC.M3.F-LE.4](#)

Trigonometric Functions

Extend the domain of trigonometric functions using the unit circle

[NC.M3.F-TF.1](#)

[NC.M3.F-TF.2a](#)

[NC.M3.F-TF.2b](#)

Model periodic phenomena with trigonometric functions

[NC.M3.F-TF.5](#)

Geometry

Overview

Congruence

Prove geometric theorems

[NC.M3.G-CO.10](#)

[NC.M3.G-CO.11](#)

[NC.M3.G-CO.14](#)

Circles

Understand and apply theorems about circles

[NC.M3.G-C.2](#)

[NC.M3.G-C.5](#)

Expressing Geometric Properties with Equations

Translate between the geometric description and the equation for a conic section

[NC.M3.G-GPE.1](#)

Geometric Measurement & Dimension

Explain volume formulas and use them to solve problems

[NC.M3.G-GMD.3](#)

Visualize relationships between two-dimensional and three-dimensional objects

[NC.M3.G-GMD.4](#)

Modeling with Geometry

Apply geometric concepts in modeling situations

[NC.M3.G-MG.1](#)

Statistics & Probability

Overview

Making Inference and Justifying Conclusions

Understand and evaluate random processes underlying statistical experiments

[NC.M3.S-IC.1](#)

Making inferences and justify conclusions from sample surveys, experiments and observational studies

[NC.M3.S-IC.3](#)

[NC.M3.S-IC.4](#)

[NC.M3.S-IC.5](#)

[NC.M3.S-IC.6](#)

Number – The Complex Number System

NC.M3.N-CN.9

Use complex numbers in polynomial identities and equations.

Use the Fundamental Theorem of Algebra to determine the number and potential types of solutions for polynomial functions.

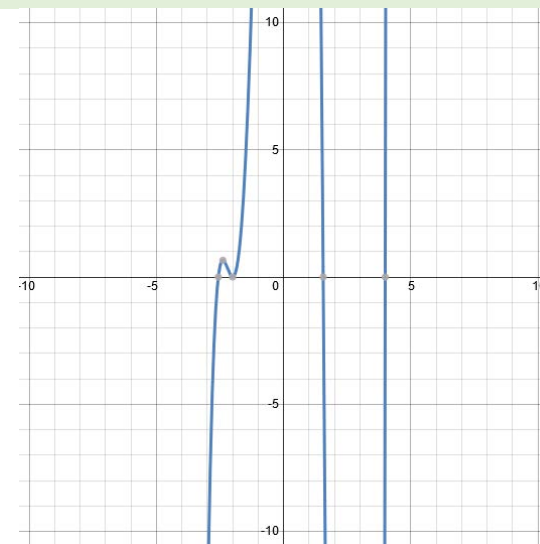
Concepts and Skills	The Standards for Mathematical Practices
<p>Pre-requisite</p> <ul style="list-style-type: none"> Understand the relationship between the factors and the zeros of a polynomial function (NC.M3.A-APR.3) <p>Connections</p> <ul style="list-style-type: none"> Interpret parts of an expression (NC.M3.A-SSE.1a) Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2) Multiply and divide rational expressions (NC.M3.A-APR.7b) Creating equations to solve or graph (NC.M3.A-CED.1, NC.M3.A-CED.2) Justify a solution method and the steps in the solving process (NC.M3.A-REI.1) Write a system of equations as an equation or write an equation as a system of equations to solve (NC.M3.A-REI.11) Finding and comparing key features of functions (NC.M3.F-IF.4, 7, 9) Building functions from graphs, descriptions and ordered pairs (NC.M3.F-BF.1a) 	<p>Connections</p> <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>2 – Reason abstractly and quantitatively 3 – Construct viable arguments and critique the reasoning of others 8 – Look for and express regularity in repeated reasoning</p> <p>Disciplinary Literacy</p> <p><i>New Vocabulary: The Fundamental Theorem of Algebra</i> Students should be able to discuss how can you determine the number of real and imaginary solutions of a polynomial.</p>
Mastering the Standard	
<p>Comprehending the Standard</p> <p>Students know The Fundamental Theorem of Algebra, which states that <i>every polynomial function of positive degree n has exactly n complex zeros (counting multiplicities)</i>. Thus a linear equation has 1 complex solution, a quadratic has two complex solutions, a cubic has three complex solutions, and so on. The zeroes do not have to be unique. For instance $(x - 3)^2 = 0$ has zeroes at $x = 3$ and $x = 3$. This is considered to have a double root or a multiplicity of two.</p> <p>Students also understand the graphical (x-intercepts as real solutions to functions) and algebraic (solutions equal to zero by methods such as factoring, quadratic formula, the remainder theorem, etc.) processes to determine when solutions to polynomials are real, rational, irrational, or imaginary.</p>	<p>Assessing for Understanding</p> <p>First, students need to be able to identify the number of solutions to a function by relating them to the degree.</p> <p>Example: How many solutions exist for the function $f(x) = x^4 - 10x + 3$?</p> <p>Students need to determine the types of solutions using graphical or algebraic methods, where appropriate.</p> <p>Example (real and imaginary solutions): How many, and what type, of solutions exist for the function $f(x) = x^4 - 10x^2 - 21x - 12$?</p> <p>Example (with multiplicity of 2): How many, and what type, of solutions exist for the function $f(x) = x^5 - 3x^4 - 27x^3 + 19x^2 + 114x - 72$?</p>

Mastering the Standard

Comprehending the Standard

Assessing for Understanding

Example: What is the lowest possible degree of the function graphed below? How do you know? What is another possible degree for the function?



Instructional Resources

Tasks

Additional Resources

[Algebra made Fundamental](#) (CPalms)
[Truncated Graph](#)
[Representing Polynomials Graphically](#)

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Algebra, Functions & Function Families

NC Math 1	NC Math 2	NC Math 3
Functions represented as graphs, tables or verbal descriptions in context		
Focus on comparing properties of linear function to <i>specific</i> non-linear functions and rate of change. <ul style="list-style-type: none"> Linear Exponential Quadratic 	Focus on properties of quadratic functions and an introduction to inverse functions through the inverse relationship between quadratic and square root functions. <ul style="list-style-type: none"> Quadratic Square Root Inverse Variation 	A focus on more complex functions <ul style="list-style-type: none"> Exponential Logarithm Rational functions w/ linear denominator Polynomial w/ degree \leq three Absolute Value and Piecewise Intro to Trigonometric Functions

A Progression of Learning of Functions through Algebraic Reasoning

The conceptual categories of Algebra and Functions are inter-related. Functions describe situations in which one quantity varies with another. The difference between the Function standards and the Algebra standards is that the Function standards focus more on the characteristics of functions (e.g. domain/range or max/min points), function definition, etc. whereas the Algebra standards provide the computational tools and understandings that students need to explore specific instances of functions. As students progress through high school, the coursework with specific families of functions and algebraic manipulation evolve. Rewriting algebraic expressions to create equivalent expressions relates to how the symbolic representation can be manipulated to reveal features of the graphical representation of a function.

Note: The Numbers conceptual category also relates to the Algebra and Functions conceptual categories. As students become more fluent with their work within particular function families, they explore more of the number system. For example, as students continue the study of quadratic equations and functions in Math 2, they begin to explore the complex solutions. Additionally, algebraic manipulation within the real number system is an important skill to creating equivalent expressions from existing functions.

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Algebra – Seeing Structure in Expressions

NC.M3.A-SSE.1a

Interpret the structure of expressions.

Interpret expressions that represent a quantity in terms of its context.

- a. Identify and interpret parts of piecewise, absolute value, polynomial, exponential and rational expressions including terms, factors, coefficients, and exponents.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Identify and interpret parts of an expression in context (NC.M2.A-SSE.1a)
Connections <ul style="list-style-type: none"> Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Interpret parts of an expression as a single entity (NC.M3.A-SSE.1b) Create and graph equations and systems of equations (NC.M3.A-CED.1, NC.M3.A-CED.2, NC.M3.A-CED.3) Interpret one variable rational equations (NC.M3.A-REI.2) Interpret statements written in piecewise function notation (NC.M3.F-IF.2) Analyze and compare functions for key features (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) Understand the effects on transformations on functions (NC.M3.F-BF.3) Interpret inverse functions in context (NC.M3.F-IF.4c) Interpret the sine function in context (NC.M3.F-TF.5)

The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>1 – Make sense of problems and persevere in solving them</p> <p>4 – Model with mathematics</p>
Disciplinary Literacy <p><i>New Vocabulary: Absolute value, piecewise function, rational function</i></p>

Mastering the Standard

Comprehending the Standard

Students need to be able to determine the meaning, algebraically and from a context, of the different parts of the expressions noted in the standard. At the basic level, this would refer to identifying the terms, factors, coefficients, and exponents in each expression.

Students must also be able to identify how these key features relate in context of word problems.

Assessing for Understanding

Students should be able to identify and **explain the meaning** of each part of these expressions.

Example: The Charlotte Shipping Company is needing to create an advertisement flyer for its new pricing for medium boxes shipped within Mecklenburg County. Based on the expressions of the function below, where c represents cost and p represent pounds, create an advertisement that discusses all the important details for the public.

$$c(p) = \begin{cases} 11.45, & p \leq 12\frac{1}{3} \\ .72p + 5.57, & p > 12\frac{1}{3} \end{cases}$$

Example: In a newspaper poll, 52% of respondents say they will vote for a certain presidential candidate. The range of the actual percentage can be expressed by the expression $|x - 4|$, where x is the actual percentage. What are the highest and lowest percentages that might support the candidate? Is the candidate guaranteed a victory? Why or why not?

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
	<p>Example: A woman invests a specific amount of money which earns compounded interest at a particular rate. This situation is represented by the equation: $A = 1000(1.023)^{2t}$. Determine the initial amount invested, the interest rate, and how often it is compounded.</p> <p>Remember: $A = P \left(1 + \frac{r}{n}\right)^{nt}$</p> <p>Example: The expression $.0013x^3 - .0845x^2 + 1.6083x + 12.5$ represents the gas consumption by the United States in billions of gallons, where x is the years since 1960. Based on the expression, how many gallons of gas were consumed in 1960? How do you know?</p> <p>Example: In the equation of the circle $x^2 + (y - 3)^2 = 16$, what does the 16 represent?</p> <p>Example: You were having a party and did not check to see how many slices each pizza was cut into at the beginning of the party. However, you assume that the pizza place would have cut all of the pizzas into equal slices. You still have 4 slices of one pizza and 3 of another. The following expression represents this situation. What does x represent in this expression?</p> $\frac{4}{x} + \frac{3}{x}$

Instructional Resources

Tasks	Additional Resources
	Rational Functions Unit Classroom Task: 4.2 (Mathematics Visions Project)

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Algebra – Seeing Structure in Expressions

NC.M3.A-SSE.1b

Interpret the structure of expressions.

Interpret expressions that represent a quantity in terms of its context.

- b. Interpret expressions composed of multiple parts by viewing one or more of their parts as a single entity to give meaning in terms of a context.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Interpret parts of a function as a single entity (NC.M2.A-SSE.1b) Interpret parts of an expression in context (NC.M3.A-SSE.1a) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 1 – Make sense of problems and persevere in solving them 4 – Model with mathematics
Connections <ul style="list-style-type: none"> Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Create and graph equations and systems of equations (NC.M3.A-CED.1, NC.M3.A-CED.2, NC.M3.A-CED.3) Interpret one variable rational equations (NC.M3.A-REI.2) Interpret statements written in function notation (NC.M3.F-IF.2) Analyze and compare functions for key features (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) Understand the effects on transformations on functions (NC.M3.F-BF.3) Interpret inverse functions in context (NC.M3.F-IF.4c) 	Disciplinary Literacy <i>New Vocabulary: piecewise function</i>

Mastering the Standard

Comprehending the Standard

Students must be able to take the multi-part expressions we engage with in Math 3 and see the different parts and what they mean to the expression in context. Students have worked with this standard in Math 1 and Math 2, so the new step is applying it to our Math 3 functions.

As we add piecewise functions and expressions in Math 3, breaking down these expressions and functions into their parts are essential to ensure understanding.

Assessing for Understanding

Students must be able to demonstrate that they can understand, analyze, and interpret the information that an expression gives in context. The two most important parts are determining what a certain situation asks for, and then how the information can be determined from the expression.

Example: The expression, $.0013x^3 - .0845x^2 + 1.6083x + 12.5$, represents the gas consumption by the United States in billions of gallons, where x is the years since 1960. Based on the expression, how many gallons of gas were consumed in 1960? How do you know?

Example: Explain what operations are performed on the inputs -2, 0, and 3 for the following expression:

$$f(x) = \begin{cases} 3x, & \text{for } x \leq 0 \\ \frac{1}{x}, & \text{for } 0 < x < 2 \\ x^3, & \text{for } x > 2 \end{cases} \quad \text{Which input is not in the domain? Why not?}$$

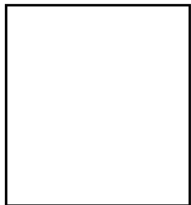
Note: Students must examine each piece of the function above to determine how to evaluate given values of the domain.

Example: Find the range using the appropriate expressions given the following domain values: -9, -6, -3, 0, 1.5, and 3.

$$g(x) = \begin{cases} -3, & \text{for } x < -6 \\ (x+1)^2, & \text{for } -6 \leq x \leq 2 \\ 2^x, & \text{for } x < 2 \end{cases}$$

Example: If the expression $(x+2)(x-2)(5x-1)$ represents the measurements from a rectangular prism, what could entire expression and each of the factors represent?

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
	<p>Example: A progressive tax system increases the percentage of income tax as the income level increases. The following piecewise function describes a certain state's income tax. Write a paragraph explaining the tax system and determine the amount of taxes paid by families with incomes of \$20,000, \$75,000, and \$160,000. Does this system seem fair? Why or why not?</p> $f(x) = \begin{cases} 0, & \text{for } x \leq 25,000 \\ 0.08x, & \text{for } 25,000 < x \leq 50,000 \\ 4000 + 0.15(x - 50,000), & \text{for } 50,000 < x \leq 125,000 \\ 15,250 + 0.3(x - 125,000), & \text{for } x > 125,000 \end{cases}$ <p>Example: In the equation of the circle $x^2 + (y - 3)^2 = 16$, what does the $y - 3$ represent?</p> <p>Example: What are the center and radius of the circle given $x^2 + 8x - 13 + y^2 - 6y + 11 = 0$?</p> <p><i>Note: For the focus of this standard, students should be able to explain how they know the next steps based on the structure of this equation.</i></p> <p>Example: Given the rectangle to the right, explain the meaning of the numerator of the following rational expression:</p> $\frac{x^2 + 3x}{x + 3}$  <p>Example: Given the expression: $a \sin(bx) + c$</p> <ol style="list-style-type: none"> What do a, b, c, and x represent? How would increasing each variable by a factor of 2 change the value of the expression? <p><i>Note: This example could also fit NC.M3.F-TF.5. For this standard, students must recognize that changing b and x have different impacts than a or c because they are “inputs” of a sine function. Teachers can give values for the variables to help students interpret. Students should notice the similarity of this expression as with function transformations (e.g., $af(bx) + c$).</i></p>

Instructional Resources

Tasks	Additional Resources
	Rational Functions Unit Classroom Task: 4.2 (Mathematics Visions Project)

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Algebra – Seeing Structure in Expressions

NC.M3.A-SSE.2

Interpret the structure of expressions.

Use the structure of an expression to identify ways to write equivalent expressions.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Justifying a solution method (NC.M2.A-REI.1)
Connections
<ul style="list-style-type: none"> Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Write an equivalent form of an exponential expression (NC.M3.A-SSE.3c) Create and graph equations and systems of equations (NC.M3.A-CED.1, NC.M3.A-CED.2, NC.M3.A-CED.3) Justify a solution method (NC.M3.A-REI.1) Solve one variable rational equations (NC.M3.A-REI.2) Analyze and compare functions for key features (NC.M3.F-IF.7, NC.M3.F-IF.9)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>7 – Look for and make use of structure</p> <p>8 – Look for and express regularity in repeated reasoning</p>
Disciplinary Literacy
<p>New Vocabulary: <i>Sum or Difference of Cubes</i></p>

Mastering the Standard

Comprehending the Standard

In Math 1 and 2, students factored quadratics. In Math 3, extend factoring to include strategies for rewriting more complicated expressions. Factoring a sum or difference of cubes, factoring a GCF out of a polynomial, and finding missing coefficients for expressions based on the factors can all be included.

This standard places a focus on student having a full understanding of several types of functions. This requires students to be familiar with the various forms of function and the procedures used to rewrite expressions.

For example, students should be able to recognize a difference of cubes and recall the procedure to rewrite the expression as a product of factors.

This standard should be applied to all function families learned throughout high school, including the expressions in rational functions, exponential functions and polynomial functions. Students in Math 3 are not expected to apply a phase shift to rewrite sine and cosine function, though this could be a good extension topic.

Assessing for Understanding

This standard can be assessed mainly by performing the algebraic manipulation. Problems could include:

Example: Factor $x^3 - 2x^2 - 35x$

Example: The expression $(x + 4)$ is a factor of $x^2 + kx - 20$. What is the value of k ? How do you know?

Example: Factor $x^3 - 8$

Example: When factoring a difference of cubes, is the trinomial factor always, sometimes or never factorable? How do you know?

Example: Rewrite the following exponential equations to show the rate of growth or decay.

a) $A(t) = 500(1.035)^t$ answer: $A(t) = 500(1 + 0.035)^t$

b) $V(t) = 15,000(0.87)^t$ answer: $V(t) = 15,000(1 - 0.13)^t$

Example: The formula for the surface area of a cylinder is often written as $V = 2rh + 2r^2$.

a) Explain the meaning of each part of the formula.

b) Solve the formula for h , in terms of r and V . What might be the benefit of this new formula?

Note: In this example, part a) aligns with NC.M3.A-SSE.1b. For part b), students in Math 3 should be able to look at the structure of the equation and use that structure to identify the best way forward. A more challenging extension would be to have students solve for r .

Mastering the Standard

Comprehending the Standard

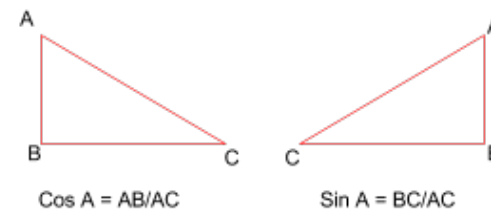
Assessing for Understanding

Example: What are the center and radius of the circle given $x^2 + 8x - 13 + y^2 - 6y + 11 = 0$?

Note: For this standard, students should be able to see structure of this equation and explain how the structure determines what they must do to answer the question.

Extension Example: Prove that $\sin\left(x - \frac{\pi}{2}\right)$ is the same as $\cos(x)$. Use the triangles if needed.

Note: As an extension to this standard, students can rewrite a sine function as a cosine function.



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Algebra – Seeing Structure in Expressions

NC.M3.A-SSE.3

Write expressions in equivalent forms to solve problems.

Write an equivalent form of an exponential expression by using the properties of exponents to transform expressions to reveal rates based on different intervals of the domain.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Use the properties of exponents to rewrite expressions with rational exponents (NC.M2.N-RN.2) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 7 – Look for and make use of structure
Connections <ul style="list-style-type: none"> Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2) Analyze and compare functions for key features (NC.M3.F-IF.7, NC.M3.F-IF.9) Building functions from graphs, descriptions and ordered pairs (NC.M3.F-BF.1a) 	Disciplinary Literacy Students should be able to explain their process of transforming an exponential expression using mathematical reasoning.

Mastering the Standard	
Comprehending the Standard Students have already learned about exponential expressions in Math 1. This standard expands on that knowledge to expect students to write equivalent expressions based on the properties of exponents. Additionally, compound interest is included in this standard. In teaching students to fully master this concept, we must explain where the common compound interest formula originates. The relationship to the common $A = P(1 + r)^t$ formula must be derived and explained.	Assessing for Understanding For students to demonstrate mastery, they must be able to convert these expressions and explain why the conversions work mathematically based on the properties of exponents. Example: Explain why the following expressions are equivalent. $2\left(\frac{1}{2}\right)^6 \quad \left(\frac{1}{2}\right)^5 \quad 2\left(\frac{1}{4}\right)^3$ Students must be able to convert an exponential expression to different intervals of the domain. Example: In 1966, a Miami boy smuggled three Giant African Land Snails into the country. His grandmother eventually released them into the garden, and in seven years there were approximately 18,000 of them. The snails are very destructive and need to be eradicated. a) Assuming the snail population grows exponentially, write an expression for the population, p , in terms of the number, t , of years since their release. b) You must present to the local city council about eradicating the snails. To make a point, you want to want to show the rate of increase per month. Convert your expression from being in terms of years to being in terms of months. <i>Modified from Illustrative Mathematics</i> https://www.illustrativemathematics.org/content-standards/tasks/638

Instructional Resources	
Tasks	Additional Resources Compound Interest Introduction

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Algebra – Arithmetic with Polynomial Expressions

NC.M3.A-APR.2

Understand the relationship between zeros and factors of polynomials.

Understand and apply the Remainder Theorem.

Concepts and Skills		The Standards for Mathematical Practices	
Pre-requisite		Connections	
<ul style="list-style-type: none">Evaluate functions (NC.M1.F-IF.2)Division of polynomials (NC.M3.A-APR.6)		<i>The following SMPs can be highlighted for this standard.</i> 7 – Look for and make use of structure 8 – Look for and express regularity in repeated reasoning	
Connections		Disciplinary Literacy	
<ul style="list-style-type: none">Understand the relationship between the factors of a polynomial, solutions and zeros (NC.M3.A-APR.3)Create and graph equations (NC.M3.A-CED.1, NC.M3.A-CED.2)Justify a solution method and the steps in the solving process (NC.M3.A-REI.1)Analyze and compare functions for key features (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9)Building functions from graphs, descriptions and ordered pairs (NC.M3.F-BF.1a)		Students should be able to accurately explain Remainder Theorem in their own words.	

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
Students must understand that the Remainder Theorem states that if a polynomial $p(x)$ is divided by any binomial $(x - c)$, <i>which does not have to be a factor of the polynomial</i> , the remainder is the same as if you evaluate the polynomial for c (meaning to evaluate $p(c)$). If the remainder $p(c) = 0$ then $(x - c)$ is a factor of $p(x)$ and c is a solution of the polynomial. Students should be able to know and apply all the Remainder Theorem. Teachers should not limit the focus to just finding roots. Students can discover this relationship by completing the division and evaluating the function for the same value to see how the remainder and the function’s value are the same.	Students should be able to apply the Remainder Theorem. Example: Let $p(x) = x^5 - x^4 + 8x^2 - 9x + 30$. Evaluate $p(-2)$. What does the solution tell you about the factors of $p(x)$? <i>Solution: $p(-2) = 32$. This means that the remainder of $\frac{x^5 - x^4 + 8x^2 - 9x + 30}{x+2}$ is $\frac{32}{x+2}$. This also means that $x + 2$ is not a factor of $x^5 - x^4 + 8x^2 - 9x + 30$.</i> Example: Consider the polynomial function: $P(x) = x^4 - 3x^3 + ax^2 - 6x + 14$, where a is an unknown real number. If $(x - 2)$ is a factor of this polynomial, what is the value of a ? Example: Let $f(x) = 3x^3 - ax^2 + bx - 8$, $f(-2) = 16$ and $f(1) = 10$. What are the values of a and b in the polynomial function?

Instructional Resources	
Tasks	Additional Resources
	Remainder Theorem Discovery

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Algebra – Arithmetic with Polynomial Expressions

NC.M3.A-APR.3

Understand the relationship between zeros and factors of polynomials.

Understand the relationship among factors of a polynomial expression, the solutions of a polynomial equation and the zeros of a polynomial function.

Concepts and Skills		The Standards for Mathematical Practices	
Pre-requisite <ul style="list-style-type: none">Understand the relationship between the linear factor of a quadratic expression and solutions and zeros (NC.M1.A-APR.3)		Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> 3 – Construct viable arguments and critique the reasoning of others 7 – Look for and make use of structure	
Connections <ul style="list-style-type: none">Understand and apply the Remainder Theorem (NC.M3.A-APR.2)Create and graph equations (NC.M3.A-CED.1, NC.M3.A-CED.2)Justify a solution method (NC.M3.A-REI.1)		Disciplinary Literacy	

Mastering the Standard	
Comprehending the Standard <p>In Math 1, students studied the relationships of factors, zeroes, and solutions as they related to quadratics. In Math 3, students will expand on these relationships to higher-order polynomials with more than two factors and/or solutions.</p> <p>It is not sufficient to allow students to use the shortcut that solutions are the “opposite” of the number in a binomial factor, because when the leading coefficient is greater than one, this is not true. For example, the factor $(2x + 3)$ does not correspond with a solution of -3. As in previous HS mathematics course, students must understand the relationship between the solutions of an equation and the zeros of a function. Additionally, they must understand the multiplicative property of zero and how it is applied to the algebraic process when solving polynomial equations.</p>	Assessing for Understanding <p>Students must understand how to set factors equal to 0 to solve a polynomial AND how to build factors from the solutions to a polynomial.</p> <p>Example: What relationship exists between factors of polynomials and their solutions? What type of solutions can exist when a polynomial is not factorable?</p> <p>Example: What are the solutions to the polynomial: $p(x) = (x - 5)(3x + 5)(x^2 - 7x + 15)$</p> <p>Example: Write two distinct polynomials, in factored form, with solutions at $1, \frac{4}{3}$, and a double root at -4.</p>

Instructional Resources	
Tasks	Additional Resources <p>Representing Polynomials Graphically</p>

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Algebra – Arithmetic with Polynomial Expressions

NC.M3.A-APR.6

Rewrite rational expressions.

Rewrite simple rational expressions in different forms; write $\frac{a(x)}{b(x)}$ in the form $q(x) + \frac{r(x)}{b(x)}$, where $a(x)$, $b(x)$, $q(x)$, and $r(x)$ are polynomials with the degree of $r(x)$ less than the degree of $b(x)$.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Long division of numerical expressions Operations with polynomial expressions (NC.M2.A-APR.1)
Connections <ul style="list-style-type: none"> Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Operations with polynomial expressions (NC.M3.A-APR.7a, NC.M3.A-APR.7b) Create and graph equations (NC.M3.A-CED.1, NC.M3.A-CED.2) Justify a solution method (NC.M3.A-REI.1) Solve one variable rational equations (NC.M3.A-REI.2) Analyze and compare functions for key features (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9)

The Standards for Mathematical Practices
Connections <i>The following SMPs can be highlighted for this standard.</i> 5 – Use appropriate tools strategically
Disciplinary Literacy If students learn synthetic division, students should be able to describe the limitations of the process.

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>In teaching this standard, students must be able to divide and simplify rational expressions by factoring and simplifying (inspection) and long division. It will be important for students to realize when each can and should be used.</p> <p>The use of synthetic division may be introduced as a method but students should recognize its limitations (division by a linear term). When students use methods that have not been developed conceptually, they often have misconceptions and make procedural mistakes due to a lack of understanding. They also lack the understanding to modify or adapt the method when faced with new and unfamiliar situations.</p> <p>Video: Synthetic Division: How to understand It by NOT doing it.</p>	<p>Students must not only be able to rewrite and divide the polynomials, but they will often need to determine the most appropriate method for performing the operation. Why questions, such as “Why did you choose inspection/long division/synthetic division to rewrite this expression?” can enhance the understanding.</p> <p>Example: Express $\frac{-x^2+4x+87}{x+1}$ in the form $q(x) + \frac{r(x)}{b(x)}$.</p> <p>Example: Find the quotient and remainder for the rational expression $\frac{x^3-3x^2+x-6}{x^2+2}$ and use them to write the expression in a different form.</p> <p>Example: Determine the best method to simplify the following expressions, and explain why your chosen method is the most appropriate.</p> <p>a) $\frac{6x^3+15x^2+12x}{3x}$ b) $\frac{x^2+9x+14}{x+7}$ c) $\frac{x^4+3x}{x^2-4}$ d) $\frac{x^3+7x^2+13x+6}{x+4}$</p>

Instructional Resources	
Tasks	Additional Resources
Combined Fuel Efficiency (Illustrative Mathematics)	Rational Functions Unit Classroom Task: 4.4 (Mathematics Visions Project)

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Algebra – Arithmetic with Polynomial Expressions

NC.M3.A-APR.7a

Rewrite rational expressions.

Understand the similarities between arithmetic with rational expressions and arithmetic with rational numbers.

- a. Add and subtract two rational expressions, $a(x)$ and $b(x)$, where the denominators of both $a(x)$ and $b(x)$ are linear expressions.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Operations with fractions Operations with polynomial expressions (NC.M2.A-APR.1) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 7 – Look for and make use of structure
Connections <ul style="list-style-type: none"> Rewrite simple rational expressions (NC.M3.A-APR.6) Multiply and divide rational expressions (NC.M3.A-APR.7b) Create and graph equations (NC.M3.A-CED.1, NC.M3.A-CED.2) Justify a solution method (NC.M3.A-REI.1) Solve one variable rational equations (NC.M3.A-REI.2) Write a system of equations as an equation or write an equation as a system of equations to solve (NC.M3.A-REI.11) Analyze and compare functions for key features (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) Building functions from graphs, descriptions and ordered pairs (NC.M3.F-BF.1a) 	Disciplinary Literacy New vocabulary: Rational <i>expression</i>

Mastering the Standard

Comprehending the Standard

Students should understand that the same addition and subtraction properties that apply to rational *numbers*, specifically fractions, also apply to rational *expressions*. In NC Math 3, students will add and subtract rational expressions to simplify rational expressions. Factoring (LCMs and GCFs) and the Identity Property of Multiplication are good concepts to pre-assess/review. It is very important that students avoid the misconception of “cross multiplying” to find common denominators, which may be an erroneous strategy carried forward from earlier work with fractions and doesn’t support mathematical understanding.

Note: NC Math 3 students will add and subtract rational expressions with *linear* denominators ONLY.

Assessing for Understanding

Students must be able to perform the operations and understand and explain the process (i.e. why they are factoring out a GCF, why they are finding a common denominator, why they are multiplying the numerator and denominator by the same factor, etc.)

Example: $\frac{3x+7}{x-2} - \frac{3x+15}{2x-4}$

Example: Simplify and explain your steps: $\frac{4x+13}{x-3} + \frac{x+2}{2x+6}$

Example: Why does multiplying a numerator and denominator by 2 NOT double the value of a rational expression?

Instructional Resources

Tasks	Additional Resources
	Rational Functions Unit Classroom Task: 4.3 (Mathematics Visions Project)

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Algebra – Arithmetic with Polynomial Expressions

NC.M3.A-APR.7b

Rewrite rational expressions.

Understand the similarities between arithmetic with rational expressions and arithmetic with rational numbers.

- b. Multiply and divide two rational expressions.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Operations with fractions Operations with polynomial expressions (NC.M2.A-APR.1) Rewrite simple rational expressions (NC.M3.A-APR.6)
Connections
<ul style="list-style-type: none"> Create and graph equations (NC.M3.A-CED.1, NC.M3.A-CED.2) Justify a solution method (NC.M3.A-REI.1) Solve one variable rational equations (NC.M3.A-REI.2) Write a system of equations as an equation or write an equation as a system of equations to solve (NC.M3.A-REI.11) Analyze and compare functions for key features (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) Building functions from graphs, descriptions and ordered pairs (NC.M3.F-BF.1a)

The Standards for Mathematical Practices
Connections
<i>The following SMPs can be highlighted for this standard.</i> 7 – Look for and make use of structure
Disciplinary Literacy

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
<p>Students should understand that the same multiplication and division properties that apply to multiplying and dividing fractions also apply to performing the same operations on rational expressions. Again, it is important to avoid short cuts and tricks (for example, cross multiplying and keep-change-flip) that do not support mathematical understanding. Prior knowledge with factoring and operations of fractions are excellent concepts from which to build.</p>	<p>Students must be able to perform the operations and understand and explain the process (i.e. why they are factoring each expression, why they can divide out common factors in the numerator and denominator, that a common denominator when dividing can be useful, etc.)</p> <p>Example: Simplify and explain your steps.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> a. $\left(\frac{2x+4}{x^2-6x}\right)\left(\frac{x^2-36}{4x+8}\right)$ </div> <div style="text-align: center;"> b. $\left(\frac{x^2-4}{x^2+2x-5}\right) \div \left(\frac{x+2}{x^2+2x-5}\right)$ </div> </div>

Instructional Resources

Tasks	Additional Resources
	Rational Functions Unit Classroom Task: 4.3 (Mathematics Visions Project)

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Algebra – Creating Equations

NC.M3.A-CED.1

Create equations that describe numbers or relationships.

Create equations and inequalities in one variable that represent absolute value, polynomial, exponential, and rational relationships and use them to solve problems algebraically and graphically.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Create one variable equations and solve (NC.M2.A-CED.1) Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b) Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2) Justify a solution method (NC.M3.A-REI.1) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 1 – Make sense of problems and persevere in solving them 4 – Model with mathematics
Connections <ul style="list-style-type: none"> Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b) Justify a solution method (NC.M3.A-REI.1) Solve one variable rational equations (NC.M3.A-REI.2) Write a system of equations as an equation or write an equation as a system of equations to solve (NC.M3.A-REI.11) Use function notation to evaluate piecewise functions (NC.M3.F-IF.2) Build functions from various representations and by combining functions (NC.M3.F-BF.1a, NC.M3.F-BF.1b) Use logarithms to express solutions to exponential equations (NC.M3.F-LE.4) 	Disciplinary Literacy <i>New Vocabulary: Absolute value equation, rational equation</i> Student should be able to explain and defend the model they chose to represent the situation.

Mastering the Standard

Comprehending the Standard

This is a modeling standard which means students choose and use appropriate mathematical equations to analyze situations. Thus, contextual situations that require students to determine the correct mathematical model and use the model to solve problems are essential.

Creating one variable equations and inequalities are included in Math 1, 2, and 3. In previous courses, students modeled with linear, exponential, quadratic, radical, and inverse variation equations. In Math 3, students will be expected to model with polynomial, rational, absolute value, and exponential equations. Students will need to analyze a problem, determine the type of equation, and set up and solve these problems. Students may need to create an equation from different representations found in the context. This makes it

Assessing for Understanding

Students should be able to create and solve problems algebraically and graphically. There should be a focus on using methods efficiently.

Example: Clara works for a marketing company and is designing packing for a new product. The product can come in various sizes. Clara has determined that the size of the packaging can be found using the function, $p(b) = b(2b + 1)(b + 5)$, where b is the shortest measurement of the product. After some research, Clara determined that packaging with $20,500 \text{ cm}^3$ will be the most appealing to customers. What are the dimensions of the package?

Example: If the world population at the beginning of 2008 was 6.7 billion and growing at a rate of 1.16% each year, in what year will the population be double?

Example: A recent poll suggests that 47% of American citizens are going to vote for the Democratic candidate for president, with a margin of error of $\pm 4.5\%$. Set up and solve an absolute value inequality to determine the range of possible percentages the candidate could earn. Based on your answer, can you determine if the Democratic candidate will win the election? Why or why not?

Mastering the Standard

Comprehending the Standard

important for students to realize that equations can be derived as a specific instance of an associated function.

Students are expected to represent the solutions of an inequality using a number line and compound inequalities using inequality and interval notation.

Assessing for Understanding

Example: In a Math 3 class, the red group has four members. Brian can solve an equation in 5 minutes, Luis can solve one in 4 minutes, Sylvia can solve one in 6 minutes, and Tierra can solve one in 3 minutes. Set up and solve an equation to determine how long will it take the group to complete a 10 problem worksheet if they work together. Is this answer accurate, based on the context? Why or why not?

Instructional Resources

Tasks

[Basketball](#) (Illustrative Mathematics)

Additional Resources

[Creating Exponential Equations](#)

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Algebra – Creating Equations

NC.M3.A-CED.2

Create equations that describe numbers or relationships.

Create and graph equations in two variables to represent absolute value, polynomial, exponential and rational relationships between quantities.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Create and graph two-variable equations (NC.M2.A-CED.2) Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b) Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 4 – Model with mathematics
Connections <ul style="list-style-type: none"> Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Understand the relationship between the factors of a polynomial, solutions and zeros (NC.M3.A-APR.3) Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b) Write the equations and inequalities of a system (NC.M3.A-CED.3) Solve one variable rational equations (NC.M3.A-REI.2) Write a system of equations as an equation or write an equation as a system of equations to solve (NC.M3.A-REI.11) Use function notation to evaluate piecewise functions (NC.M3.F-IF.2) Analyze and compare functions (NC.M3.F-IF.7, NC.M3.F-IF.9) Build functions from various representations and by combining functions (NC.M3.F-BF.1a, NC.M3.F-BF.1b) Use logarithms to express solutions to exponential equations (NC.M3.F-LE.4) 	Disciplinary Literacy New Vocabulary: Absolute value equation, rational equation

Mastering the Standard

Comprehending the Standard

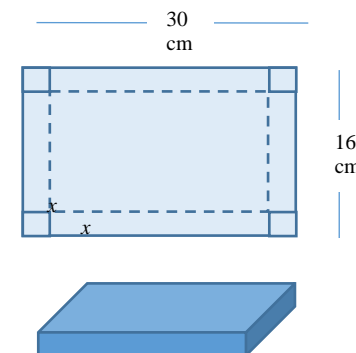
This is a modeling standard which means students choose and use appropriate mathematics to analyze situations. Thus, contextual situations that require students to determine the correct mathematical model and use the model to solve problems are essential. In A-CED.1, writing and solving an equation is emphasized while in this standard (A-CED.2), graphing the equation to determine key features is an essential skill.

This standard is included in Math 1, 2, and 3. Generally in all three courses, students create equations in two variables and graph them on coordinate axes. Students graphed exponential equations in In Math 3, absolute value, polynomial, and rational graphs are introduced.

Assessing for Understanding

Rate of growth and decay, work rate (and other rates), geometric, and other real-world examples provide the context for many of these problems.

Example: A company is manufacturing an open-top rectangular box. They have 30 cm by 16 cm sheets of material. The bins are made by cutting squares the same size from each corner of a sheet, bending up the sides, and sealing the corners. Create an equation relating the volume V of the box to the length of the corner cut out x . Graph the equation and identify the dimensions of the box that will have the maximum volume. Explain.



Mastering the Standard

Comprehending the Standard

Assessing for Understanding

Example: A biology student is studying bacterial growth. She was surprised to find that the population of the bacteria doubled every hour.

1. Complete the following table and plot the data.

Hours into study	0	1	2	3	4
Population (thousands)	4				

2. Write an equation for P , the population of the bacteria, as a function of time, t , and verify that it produces correct populations for $t = 1, 2, 3$, and 4.

<https://www.illustrativemathematics.org/content-standards/tasks/385>

Example: You are throwing a birthday party at a bowling alley for your little brother. It costs \$75 to rent a room, plus an additional cost of \$4.50 per child. Write and graph a model that gives the average cost per child.

Instructional Resources

Tasks

[Cockroaches](#) (2016 Just in Time Virtual Session)

Additional Resources

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Algebra – Creating Equations

NC.M3.A-CED.3

Create equations that describe numbers or relationships.

Create systems of equations and/or inequalities to model situations in context.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Write the equations for a system (NC.M2.A-CED.3) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b) Create and graph two variable equations (NC.M3.A-CED.2)
Connections
<ul style="list-style-type: none"> Write a system of equations as an equation or write an equation as a system of equations to solve (NC.M3.A-REI.11) Use function notation to evaluate piecewise functions (NC.M3.F-IF.2)

The Standards for Mathematical Practices
Connections
<p><i>The following SMPs can be highlighted for this standard.</i></p> <p>1 – Make sense of problems and persevere in solving them</p> <p>4 – Model with mathematics</p>
Disciplinary Literacy
Students should justify the chosen models of each equation with mathematical reasoning.

Mastering the Standard	
<p>Comprehending the Standard</p> <p>In Math 3, the systems of equations and inequalities that must be mastered include absolute value functions. In previous courses, students have worked with systems including linear and quadratic functions.</p> <p>Function types are not limited in this standard as in previous courses. All function types are potential components of systems in Math 3. Students are not expected to solve complex systems algebraically, but should focus on more efficient method such as tables, graphs, and using technology. (Solving these systems algebraically can be an extension topic.)</p>	<p>Assessing for Understanding</p> <p>In assessing this standard, graphical solutions can be highlighted using technology. Ideally, the functions and equations will come from a context.</p> <p>Example: After receiving his business degree from UNC-Chapel Hill, John is offered positions with two companies. Company A offers him \$80,000 per year, with a \$1,000 increase every year. Company B offers him \$60,000 per year with a 4% increase every year.</p> <ol style="list-style-type: none"> After how many years will the Company B salary be higher than Company A? Which offer would you choose? Why?

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Algebra – Reasoning with Equations and Inequalities

NC.M3.A-REI.1

Understand solving equations as a process of reasoning and explain the reasoning.

Justify a solution method for equations and explain each step of the solving process using mathematical reasoning.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Justify a solution method and the steps in the solving process (NC.M2.A-REI.1) Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2) Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Understand the relationship between the factors of a polynomial, solutions and zeros (NC.M3.A-APR.3) Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b)
Connections <ul style="list-style-type: none"> Creating one variable equations (NC.M3.A-CED.1) Solve one variable rational equations (NC.M3.A-REI.2) Use logarithms to express solutions to exponential equations (NC.M3.F-LE.4)

The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>3 – Construct viable arguments and critique the reasoning of others</p>
Disciplinary Literacy <p>Students should be able to explain why it is necessary to write two equations to solve an absolute value equation.</p>

Mastering the Standard	
Comprehending the Standard <p>This standard is included in Math 1, 2 and 3. In Math 3, students should extend their knowledge of all equations they are asked to solve.</p> <p>When solving equations, students will use mathematical reasoning to justify and explain each step obtained from the previous step, assuming the original equation has a solution, and develop an argument that justifies their method.</p> <p>Students do not have to use the proper names of the properties of operations and equality, but they should recognize and use the concepts associated with the properties.</p>	Assessing for Understanding <p>Solving equations including justifications for each step, error analysis of solutions to equations, and comparing and analyzing different methods are all appropriate methods of assessing this standard.</p> <p>Example: Julia is solving an absolute value inequality in class and has become stuck. Show Julia the next step and write down the explanation for that step so she can reference it on other problems.</p> <p>Julia's steps:</p> $2 x + 5 - 3 \leq 10$ $2 x + 5 \leq 13$ $ x + 5 \leq 6.5$ <p>Example: Describe your process for solving the following polynomial and explain the mathematical reasoning for each step: $x^3 + 4x^2 + x = 6$.</p> <p>Example: This rational equation has been solved using two different methods.</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Method 1</p> $\frac{1}{x-8} - 1 = \frac{7}{x-8}$ $\frac{1}{x-8} - 1\left(\frac{x-8}{x-8}\right) = \frac{7}{x-8}$ $\frac{1}{x-8} + \left(\frac{-x+8}{x-8}\right) = \frac{7}{x-8}$ $\frac{-x+9}{x-8} = \frac{7}{x-8}$ $-x+9 = 7$ $x = 2$ </div> <div style="text-align: center;"> <p>Method 2</p> $\frac{1}{x-8} - 1 = \frac{7}{x-8}$ $(x-8)\left(\frac{1}{x-8} - 1\right) = \left(\frac{7}{x-8}\right)(x-8)$ $1 - (x-8) = 7$ $9 - x = 7$ $x = 2$ </div> </div> <div style="margin-top: 20px;"> <p>a) Justify each step using a property of equality.</p> <p>b) How do the solution methods compare?</p> <p>c) Which method would you most likely use? Justify why.</p> </div>

Mastering the Standard

Comprehending the Standard

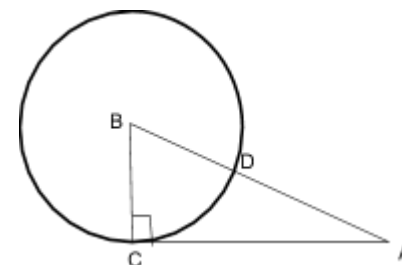
Assessing for Understanding

Example: Solve the following three equations for x . Explain the rationale for the differences in your steps and solutions.

- a) $2^6 = x$
- b) $3(2)^6 = x$
- c) $2^x = 6$
- d) $3(2)^x = 6$

Example: The volume of a sphere is 523.6 in^3 . Determine the radius of the sphere and justify each step of your algebraic reasoning.

Example: Triangle ABC is a right triangle, with AC tangent to circle B, $AC = 8$ and $AD = 4$. How would you calculate the radius of Circle B? Justify your reasoning.



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Algebra – Reasoning with Equations and Inequalities

NC.M3.A-REI.2

Understand solving equations as a process of reasoning and explain the reasoning.

Solve and interpret one variable rational equations arising from a context, and explain how extraneous solutions may be produced.

Concepts and Skills		The Standards for Mathematical Practices	
Pre-requisite		Connections	
<ul style="list-style-type: none">Solve and interpret one variable inverse variation and square root equations and explain extraneous solutions (NC.M2.A-REI.2)Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b)Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2)Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b)Justify a solution method and each step in the solving process (NC.M3.A-REI.1)		<i>The following SMPs can be highlighted for this standard.</i>	
Connections		Disciplinary Literacy	
<ul style="list-style-type: none">Creating one variable equations (NC.M3.A-CED.1)Analyze and compare functions (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9)		<i>New Vocabulary: Rational equation, extraneous solution</i> Students should be able to explain when a rational equation will have an extraneous solution.	

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>Students need to understand the process of solving rational equations, including finding the common denominator of all terms. It is important to keep in mind the limitations placed in NC.M3.A-APR.7.</p> <p>Students also need to understand the relationship between rates and rational expressions, such as $peed = \frac{distance}{time}$.</p> <p>Students should understand that the process of algebraically solving an equation can produce extraneous solutions. Students studied this in Math 2 in connection to square root functions. When teaching this standard, it will be important to link to the concept of having a limited domain, not only by the context of a problem, but also by the nature of the equation.</p> <p>Graphically, extraneous solution can be linked to discontinuities on the graph.</p>	<p>To master this standard, students must be able to set up, solve, and evaluate the solutions to “real-world” rational equations.</p> <p>Example: In a Math 3 class, the red group has four members. Brian can solve a rational equation in 5 minutes, Luis can solve one in 4 minutes, Sylvia can solve one in 6 minutes, and Tierra can solve one in 3 minutes. Set up and solve a rational equation to determine how long will it take the group to complete a 10 problem worksheet if they work together. Is this answer accurate, based on the context? Why or why not?</p> <p>Additionally, students must be able to solve rational equations and understand how extraneous solutions can be produced. Graphic representations can often be used to find real solutions, but students must be able to identify when their algebraic solving process creates an extraneous solution.</p> <p>Example: Consider the following equation.</p> $\frac{x^2 + x - 2}{x + 2} = -2$ <p>Here are two algebraic methods that can be used to solve this equation.</p>

Mastering the Standard			
Comprehending the Standard	Assessing for Understanding		
	<div>Method 1: $\frac{x^2 + x - 2}{x + 2} = -2$$\frac{(x + 2)(x - 1)}{x + 2} = -2$$x - 1 = -2$$x = -1$</div>	<div>Method 2: $\frac{x^2 + x - 2}{x + 2} = -2$$x^2 + x - 2 = -2(x + 2)$$x^2 + x - 2 = -2x - 4$$x^2 + 3x + 2 = 0$$(x + 2)(x + 1) = 0$$x = -2, -1$</div>	<div>Verify that each step in the two methods is correct and answer the following questions. a) Why does Method 2 produce two solutions? b) Looking at original equation, how can you tell which of the solutions is extraneous?</div> <div>Graph the function $f(x) = \frac{x^2+x-2}{x+2}$ on a graphing calculator or app. a) What do you notice about the graph? b) Zoom into where the extraneous solution would be on the grid. What do you notice? c) What are the implications of just looking at the graph for the solutions? d) Now look at the table of the function. What do you notice?</div>
	<div>Example: You are throwing a birthday party at a bowling alley for your little brother. It costs \$75 to rent a room, plus an additional cost of \$4.50 per child. If you only want to spend an average of \$17 per child, how many children can you invite?</div> <div>Example: Your Mom can clean your entire house in 3 hours. However, your dad takes 5 hours to clean the house. Determine how long it will take for them to clean the house if they work together.</div>		

Instructional Resources	
Tasks	Additional Resources
	Rational Functions Unit Classroom Task: 4.7 (Mathematics Visions Project)

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Algebra – Reasoning with Equations and Inequalities

NC.M3.A-REI.11

Represent and solve equations and inequalities graphically

Extend an understanding that the x -coordinates of the points where the graphs of two equations $y = f(x)$ and $y = g(x)$ intersect are the solutions of the equation $f(x) = g(x)$ and approximate solutions using a graphing technology or successive approximations with a table of values.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b)
Connections
<ul style="list-style-type: none"> Create equation to graph and solve (NC.M3.A-CED.1, NC.M3.A-CED.2, NC.M3.A-CED.3)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>4 – Model with mathematics</p>
Disciplinary Literacy
<p>Students should be able to explain how solutions obtained through algebraic methods and graphing can differ and understand the benefits and limitations of graphing.</p>

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>This standard is included in Math 1, 2, and 3. In previous courses, students studied linear, exponential and quadratic functions. In Math 3, the type of function is not limited. Students are expected to find a solution to any equation or system using tables, graphs and technology.</p> <p>Visual examples of rational equations explore the solution as the intersection of two functions and provide evidence to discuss how extraneous solutions do not fit the model.</p>	<p>Graphical solutions, often using technology, should be highlighted in assessing student mastery of this standard.</p> <p>Example: Graph the following system and approximate solutions for $f(x) = g(x)$. $f(x) = \frac{x+4}{2-x} \text{ and } g(x) = x^3 - 6x^2 + 3x + 10$</p> <p>From the standard, we build that $f(x) = g(x)$ where $f(x) = y_1$ and $g(x) = y_2$</p> <p>Example: Use technology to solve $1.5^{2x} + 3x = 15$, treating each side of the statement as two equations of a system.</p> <p><i>Note: Algebraically solving equations with 'e' is not an expectation of Math 3. Students should be able to solve any equations using a graphing technology.</i></p> <p>Example: Solve the equation $5^{4x} = 2^{8x}$ graphically. Use the answer to show that the equation holds true for the x-value you find.</p>

Instructional Resources	
Tasks	Additional Resources
	<p>Rational Functions Unit Classroom Task: 4.7 (Mathematics Visions Project)</p>

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Algebra, Functions & Function Families

NC Math 1	NC Math 2	NC Math 3
Functions represented as graphs, tables or verbal descriptions in context		
Focus on comparing properties of linear function to <i>specific</i> non-linear functions and rate of change. <ul style="list-style-type: none"> Linear Exponential Quadratic 	Focus on properties of quadratic functions and an introduction to inverse functions through the inverse relationship between quadratic and square root functions. <ul style="list-style-type: none"> Quadratic Square Root Inverse Variation 	A focus on more complex functions <ul style="list-style-type: none"> Exponential Logarithm Rational functions w/ linear denominator Polynomial w/ degree \leq three Absolute Value and Piecewise Intro to Trigonometric Functions

A Progression of Learning of Functions through Algebraic Reasoning

The conceptual categories of Algebra and Functions are inter-related. Functions describe situations in which one quantity varies with another. The difference between the Function standards and the Algebra standards is that the Function standards focus more on the characteristics of functions (e.g. domain/range or max/min points), function definition, etc. whereas the Algebra standards provide the computational tools and understandings that students need to explore specific instances of functions. As students' progress through high school, the coursework with specific families of functions and algebraic manipulation evolve. Rewriting algebraic expressions to create equivalent expressions relates to how the symbolic representation can be manipulated to reveal features of the graphical representation of a function.

Note: The Numbers conceptual category also relates to the Algebra and Functions conceptual categories. As students become more fluent with their work within particular function families, they explore more of the number system. For example, as students continue the study of quadratic equations and functions in Math 2, they begin to explore the complex solutions. Additionally, algebraic manipulation within the real number system is an important skill to creating equivalent expressions from existing functions.

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Functions – Interpreting Functions

NC.M3.F-IF.1

Understand the concept of a function and use function notation.

Extend the concept of a function by recognizing that trigonometric ratios are functions of angle measure.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Define a function (NC.M1.F-IF.1) Verify experimentally that the side ratios in similar triangles are properties of the angle measures in the triangle (NC.M2.G-SRT.6) Understand radian measure of an angle (NC.M3.F-TF.1)
Connections
<ul style="list-style-type: none"> Analyze and compare functions in various representations (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) Build an understanding of trig functions in relation to its radian measure (NC.M3.F-TF.2a, NC.M3.F-TF.2b) Investigate the parameters of the sine function (NC.M3.F-TF.5)

The Standards for Mathematical Practices
Connections
<i>The following SMPs can be highlighted for this standard.</i>
Disciplinary Literacy
Students should be able to discuss the output of trig functions as unit rates.

Mastering the Standard

Comprehending the Standard

This is an extension of previous learning. Students should already understand function notation, the correspondence of inputs and outputs, and evaluating functions. In Math 3, students should build an understanding of the unique relationship between the measure of the angle and the value of the particular trig ratio.

In Math 3, students build an understanding of radian measure. See NC.M3.F-TF.1 for more information.

Students should also begin to see the graphical representations of trig functions, both on a unit circle and on a graph in which the domain is the measure of the angle and the range is the value of the associated trig ratio. On the unit circle, the input is the measure of the angle and the output of the sine function is the y-coordinate of the vertex of the formed triangle and the output of the cosine function is the x-coordinate of the vertex of the formed triangle. See NC.M3.F-TF.2a and NC.M3.F-TF.2b for more information.

Assessing for Understanding

Students should be able to create trig functions in various representations, recognizing that the domain of a trig function is the measure of the angle.

Example: Complete the function table for $f(\theta) = \sin \theta$ and $f(\theta) = \cos \theta$ and complete the following.

θ	$\sin \theta$	$\cos \theta$	θ	$\sin \theta$	$\cos \theta$
0			π		
$\frac{\pi}{6}$			$\frac{7\pi}{6}$		
$\frac{\pi}{4}$			$\frac{5\pi}{4}$		
$\frac{\pi}{3}$			$\frac{4\pi}{3}$		
$\frac{\pi}{2}$			$\frac{3\pi}{2}$		
$\frac{2\pi}{3}$			$\frac{5\pi}{3}$		
$\frac{3\pi}{4}$			$\frac{7\pi}{4}$		
$\frac{5\pi}{6}$			$\frac{11\pi}{6}$		

Based on the table:

- Describe in your own words the relationship you see between the measure of the angle and the sine function.
- If you were to graph $f(\theta) = \sin \theta$, what would it look like? What would be some of the key feature?
- Describe in your own words the relationship between the measure of the angle and the cosine function.
- If you were to graph $f(\theta) = \cos \theta$, what would it look like? What would be some of the key feature?
- How does $\sin \theta$ and $\cos \theta$ relate to each other?

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Functions – Interpreting Functions

NC.M3.F-IF.2

Understand the concept of a function and use function notation.

Use function notation to evaluate piecewise defined functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Evaluate a function for inputs in their domain and interpret in context (NC.M1.F-IF.2) Interpret a function in terms of the context by relating its domain and range to its graph (NC.M1.F-IF.5) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b)
Connections
<ul style="list-style-type: none"> Create equation to graph and solve (NC.M3.A-CED.1, NC.M3.A-CED.2, NC.M3.A-CED.3) Analyze and compare functions in various representations (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>6 – Attend to precision</p>
Disciplinary Literacy
<p><i>New Vocabulary: piecewise function</i></p> <p>Students should be able how they know a point is a solution to piecewise defined function.</p>

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>The new concept students must understand from this standard is the notation of piecewise functions – mainly, that the function must be evaluated using different function rules for the different inputs in different domains. The function rules can include the new functions for this course (polynomial, rational, exponential) and functions from previous courses (linear, quadratic, root, etc.)</p> <p>Additionally, students must recognize from word problems why certain domains apply to certain function rules.</p> <p>A great introduction to piecewise functions could use absolute value as a piecewise function of two linear functions. Students take a function they are learning in this course and break it into two functions they have already learned in Math 1.</p>	<p>In assessing this standard, students must be able to evaluate all types of functions, and they must be able to determine the appropriate domain to use for each input value.</p> <p>Example: For the following function: $h(x) = \begin{cases} 2^x, & x < -3 \\ \frac{3}{x}, & x \geq -3 \end{cases}$</p> <ol style="list-style-type: none"> Evaluate $h(-4)$. Evaluate $3h(0) + 2h(-3) - h(-6)$. What is the domain of $h(x)$? Explain your answer. <p>Additionally, students must be able to explain the context of piecewise functions and how their domains apply.</p> <p>Example: A cell phone company sells its monthly data plans according to the following function, with $f(x)$ representing the total price and x representing the number of gigabytes of data used.</p> $f(x) = \begin{cases} 19.95x + 60, & \text{for } 0 \leq x \leq 3 \\ 9.95x + 75, & \text{for } 3 < x \leq 6 \\ 125, & \text{for } x > 6 \end{cases}$ <ol style="list-style-type: none"> If a customer uses 3 GB of data, how much will she pay? How many GB of data are required so a subscriber does not pay any extra money per GB? If you use 2.5 GB of data per month, what plan will be the cheapest? How many GB of monthly data will make plan B's price equal to plan C?

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Functions – Interpreting Functions

NC.M3.F-IF.4

Interpret functions that arise in applications in terms of the context.

Interpret key features of graphs, tables, and verbal descriptions in context to describe functions that arise in applications relating two quantities to include periodicity and discontinuities.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Interpret key features from graph, tables, and descriptions (NC.M2.F-IF.4) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b) Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1) Use function notation to evaluate piecewise functions (NC.M3.F-IF.2) 	Connections <p>The following SMPs can be highlighted for this standard.</p> <p>4 – Model with mathematics</p>
Connections <ul style="list-style-type: none"> Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b) Solve one variable rational equations (NC.M3.A-REI.2) Analyze and compare functions (NC.M3.F-IF.7, NC.M3.F-IF.9) Build functions given a graph, description or ordered pair. (NC.M3.F-BF.1a) Use graphs, tables and description to work with inverse functions (NC.M3.F-BF.4a, NC.M3.F-BF.4b, NC.M3.F-BF.4c) Use tables and graphs to understand relationships in trig functions (NC.M3.F-TF.2a, NC.M3.F-TF.2b, NC.M3.F-TF.5) 	Disciplinary Literacy <p><i>New Vocabulary: periodicity, discontinuity</i></p> <p>Students should be able to justify their identified key features with mathematical reasoning.</p>

Mastering the Standard

Comprehending the Standard

This standard is included in Math 1, 2 and 3. Throughout all three courses, students interpret the key features of graphs and tables for a variety of different functions. In Math 3, extend to more complex functions represented by graphs and tables and focus on interpreting key features of all function types. Also, include periodicity as motion that is repeated in equal intervals of time and discontinuity as values that are not in the domain of a function, either as asymptotes or “holes” in the graph.

No limitations are listed with this standard. This means that all function types, even those found in more advanced courses. Students do

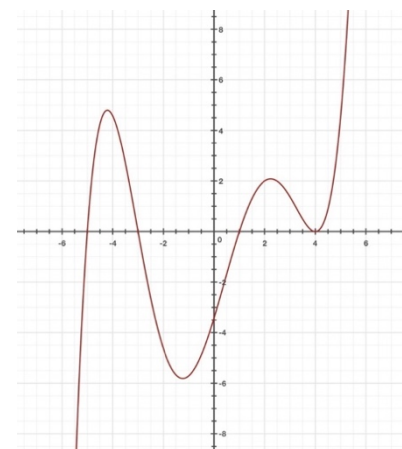
Assessing for Understanding

This standard must be assessed using three important forms of displaying our functions: graphs, tables, and verbal descriptions/word problems. Students must be able to interpret each and how they apply to the key input-output values.

Example: For the function below, label and describe the key features. Include intercepts, relative max/min, intervals of increase/decrease, and end behavior.

Example: Jumper horses on carousels move up and down as the carousel spins. Suppose that the back hooves of such a horse are six inches above the floor at their lowest point and two-and-one-half feet above the floor at their highest point. Draw a graph that could represent the height of the back hooves of this carousel horse during a half-minute portion of a carousel ride.

Example: For the function to the right, label and describe the key features. Include intercepts, relative max/min, intervals of increase/decrease, and end behavior.



Mastering the Standard

Comprehending the Standard

not have to be able to algebraically manipulate a function in order to identify the key features found in graphs, tables, and verbal descriptions.

This is in contrast to NC.M3.F-IF.7, in which the specific function types are included. Students can work algebraically with those listed types and can analyze those functions in greater detail.

Students are expected to use and interpret compound inequalities using inequality and interval notation to describe key features when appropriate.

Assessing for Understanding

Example: Over a year, the length of the day (the number of hours from sunrise to sunset) changes every day. The table below shows the length of day every 30 days from 12/31/97 to 3/26/99 for Boston Massachusetts.

Data on length of day

Date	12/31	1/30	3/1	3/31	4/30	5/30	6/29	7/29	8/28	9/27	10/27	11/26	12/26	1/25	2/24	3/26
Day Number	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450
Length (hours)	9.1	9.9	11.2	12.7	14.0	15.0	15.3	14.6	13.3	11.9	10.6	9.5	9.1	9.7	11.0	12.4

During what part of the year do the days get longer? Support your claim using information provided from the table.

Example: Peyton has a savings account at First National Bank. The amount of money in the account grows exponentially. The table shows the amount of money in her account each year.

- What is the y-intercept? What does it represent in the context of this problem?
- Find the interest rate Peyton is earning on her money.

Example: The junior class is planning prom for this school year. The venue costs \$1,200 to rent and there is an additional cost of \$20 per person for food. Write a function to model the average cost per person at prom. Where is the vertical asymptote of this function and what does it represent in this problem?

t	f(t)
0	\$1200
1	\$1254
2	\$1310.40
3	\$1369.40
4	\$1431
5	\$1495.40

Instructional Resources

Tasks

Additional Resources

[Rational Functions Unit](#) Classroom Task: 4.2, 4.6, 4.7 (Mathematics Visions Project)

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Functions – Interpreting Functions

NC.M3.F-IF.7

Analyze functions using different representations.

Analyze piecewise, absolute value, polynomials, exponential, rational, and trigonometric functions (sine and cosine) using different representations to show key features of the graph, by hand in simple cases and using technology for more complicated cases, including: domain and range; intercepts; intervals where the function is increasing, decreasing, positive, or negative; rate of change; relative maximums and minimums; symmetries; end behavior; period; and discontinuities.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Analyze functions using different representations to show key features (NC.M2.F-IF.7) Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b) Use the structure of an expression to identify ways to write equivalent expressions (NC.M3.A-SSE.2) Write an equivalent form of an exponential expression (NC.M3.A-SSE.3c) Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Rewrite rational expressions (NC.M3.A-APR.6, NC.M3.A-APR.7a, NC.M3.A-APR.7b) Solve one variable rational equations (NC.M3.A-REI.2) Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1) Use function notation to evaluate piecewise functions (NC.M3.F-IF.2) 	Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>4 – Model with mathematics</p> <p>6 – Attend to precision</p>
Connections <ul style="list-style-type: none"> Create and graph equations in two variables (NC.M3.A-CED.2) Analyze graphs and tables and compare functions (NC.M3.F-IF.4, NC.M3.F-IF.9) Build functions (NC.M3.F-BF.1a, NC.M3.F-BF.1b) Understand the effects of transformations on functions (NC.M3.F-BF.3) Use graphs, tables and description to work with inverse functions (NC.M3.F-BF.4a, NC.M3.F-BF.4b, NC.M3.F-BF.4c) Compare the end behavior of functions using the rate of change (NC.M3.F-LE.3) Use tables and graphs to understand relationships in trig functions (NC.M3.F-TF.2a, NC.M3.F-TF.2b, NC.M3.F-TF.5) 	Disciplinary Literacy <p><i>New Vocabulary: periodicity, discontinuity</i></p> <p>Students should discuss which representation best shows each of the key features.</p>

Mastering the Standard

Comprehending the Standard

In previous math courses, students have identified the characteristic of graphs of other functions, including linear, quadratic, exponential, radical, and inverse variation functions. They should be familiar with the concept of intercepts, domain, range, intervals increasing/decreasing, relative maximum/minimum, and end behavior.

Assessing for Understanding

In assessing this standard, students must demonstrate their ability to represent and determine the key features from algebraic and graphical representations of the functions.

Example: Graph $g(x) = x^3 + 5x^2 + 2x - 8$.

- Identify zeroes.
- Discuss the end behavior.
- In what intervals is the function increasing? Decreasing?

Mastering the Standard

Comprehending the Standard

In Math 3, these concepts are extended to piecewise, absolute value, polynomials, exponential, rational, and sine and cosine functions. Discontinuity (asymptotes/holes) and periodicity are new features of functions that must be introduced. The intent of this standard is for students to find discontinuities in tables and graphs and to recognize their relationship to functions. Students are not expected to find an asymptote from a function. (This could be an extension topic.)

Students are expected to use and interpret compound inequalities using inequality and interval notation to describe key features when appropriate.

Assessing for Understanding

Example: Graph $y = 3 \sin(x) - 5$ and answer the following questions:

- What is the period?
- For the domain of $-2\pi < x < 2\pi$, identify any relative maxima and minima, intervals of increasing and decreasing, and lines of symmetry.

Example: For $f(x) = \frac{x+4}{2-x}$, discuss end behavior and any discontinuities.

Example: Given the following piecewise function $h(x) = \begin{cases} x^2, & -3 \leq x < 3 \\ 2-x, & 3 \leq x < 7 \end{cases}$ discuss the key features, including domain and range, intercepts, relative maximum and minimums, end behavior and discontinuities.

Example: If an adult takes 600 mg of ibuprofen, the amount remaining in their system can be modeled by the equation $I(t) = 600(0.72)^t$ where t represents the number of hours since taking the medicine.

- What is the y-intercept of the graph and what does it represent?
- At what rate is the body eliminating the drug?
- Over what interval of time will there be at least 100 gm of ibuprofen in the person's body?

Instructional Resources

Tasks

[Running Time](#) (Illustrative Mathematics)

Additional Resources

[Rational Functions Unit](#) Classroom Task: 4.1, 4.2, 4.6, 4.7 (Mathematics Visions Project)

[Polynomial Functions Unit](#) Classroom Task: 3.3 (Mathematics Visions Project)

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Functions – Interpreting Functions

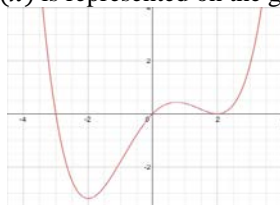
NC.M3.F-IF.9

Analyze functions using different representations.

Compare key features of two functions using different representations by comparing properties of two different functions, each with a different representation (symbolically, graphically, numerically in tables, or by verbal descriptions).

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Analyze the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7)
Connections

The Standards for Mathematical Practices
Connections
<i>The following SMPs can be highlighted for this standard.</i>
Disciplinary Literacy
<i>New Vocabulary: periodicity, discontinuity</i>
Students should discuss how the comparison of a functions leads to a mathematical understanding, such as with transformations and choosing better models.

Mastering the Standard											
<div>Comprehending the Standard</div> <p>This standard is included in Math 1, 2 and 3. Throughout all three courses, students compare properties of two functions. The representations of the functions should vary: table, graph, algebraically, or verbal description.</p> <p>In Math 3, this standard can include two functions of any type students have learned in high school math in any representation. Comparing the key features should be the focus of the teaching for this standard, so the actual functions involved are not as important.</p> <p>Students are expected to use and interpret compound inequalities using inequality and interval notation to describe key features when appropriate.</p>	<div>Assessing for Understanding</div> <p>In assessing this standard, students must demonstrate that they can not only identify, but compare, the key features of two different functions. Appropriate question stems could include: Which is less/greater; Which will have a greater value at $x = \underline{\hspace{1cm}}$; Which function has the higher maximum/lower minimum; etc.</p> <p>Examples: If $f(x) = -(x + 7)^2(x - 2)$ and $g(x)$ is represented on the graph.</p> <div></div> <div><div>a. What is the difference between the zero with the least value of $f(x)$ and the zero with the least value of $g(x)$?</div><div>b. Which has the largest relative maximum?</div><div>c. Describe their end behaviors. Why are they different? What can be said about each function?</div></div> <p>Example: Frank invested \$2,000 into a savings account earning 2.5% interested annually. Paul invested money into a different account at the same time as Frank. The table below shows the amount of money in Paul’s account after t years.</p> <table><tr><th>Time in years (t)</th><th>1</th><th>2</th><th>3</th><th>4</th></tr><tr><th>$P(t)$</th><td>\$1560</td><td>\$1622.40</td><td>\$1687.30</td><td>\$1754.79</td></tr></table> <div><div>a) Who had the larger initial investment?</div><div>b) Whose is earning a higher interest rate?</div><div>c) Over what interval of time will Frank have more money in his account? (show both inequality and interval notation)</div><div>d) Over what interval of time will Paul have more money in his account? (show both inequality and interval notation)</div></div>	Time in years (t)	1	2	3	4	$P(t)$	\$1560	\$1622.40	\$1687.30	\$1754.79
Time in years (t)	1	2	3	4							
$P(t)$	\$1560	\$1622.40	\$1687.30	\$1754.79							

Mastering the Standard

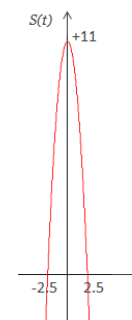
Comprehending the Standard

Assessing for Understanding

Example: Two objects dropped downward at the same time from a top of building. For both functions, t represents seconds and the height is represented in feet. The function's data of the first object is given by this table.

t	$s(t)$
0	20
2.5	15
3.5	10
4.3	5
5	0

The function's graph of the second object is shown at the right.



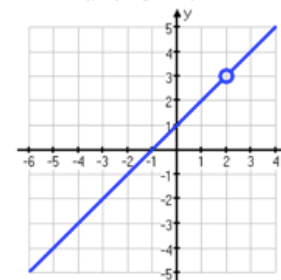
- Which object was dropped from a greater height? Explain your answer.
- Which object hit the ground first? Explain your answer.
- Which object fell at a faster rate (in ft/sec)? Explain your answer.

Example: Find the difference between the x-values of the discontinuities for the two functions below.

Function 1:

$$\frac{x^2 - 5x + 6}{x - 3}$$

Function 2:



Instructional Resources

Tasks

Additional Resources

[Polynomial Functions Unit](#) Classroom Task: 3.3 (Mathematics Visions Project)

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Functions – Building Functions

NC.M3.F-BF.1a

Build a function that models a relationship between two quantities.

Write a function that describes a relationship between two quantities.

- a. Build polynomial and exponential functions with real solution(s) given a graph, a description of a relationship, or ordered pairs (include reading these from a table).

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Build quadratic functions given a graph, description, or ordered pair (NC.M2.F-BF.1) Create equation to graph and solve (NC.M3.A-CED.1, NC.M3.A-CED.2) Analyze the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7)
Connections <ul style="list-style-type: none"> Use the Fundamental Theorem of Algebra (NC.M3.N-CN.9) Write an equivalent form of an exponential expression (NC.M3.A-SSE.3c) Understand and apply the Remainder Theorem (NC.M3.A-APR.2) Understand the effects of transforming functions (NC.M3.F-BF.3)

The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>4 – Model with mathematics</p>
Disciplinary Literacy <p>Students should be able to discuss when multiple models can describe the information given, for example, when given the two roots, multiple models can contain those roots.</p>

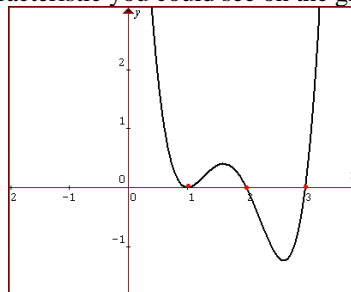
Mastering the Standard																		
Comprehending the Standard			Assessing for Understanding															
<p>This standard relates to building functions in two different contexts – polynomial (with real solutions) and exponential. In many Math 3 courses, it will be covered in two different units.</p> <p>When building polynomial functions, only those with real solutions are considered. The relationship between solutions and factors, multiplicity and graphs, and the leading coefficient’s sign relating to the end behaviors are all essential to build these functions.</p> <p>When building exponential functions, students must be able to determine the initial value (a) and rate of change (b) from the table, graph, or description presented. These problems can include those with compounding interest and doubling time/half-life.</p>			<p>For both functions, it is important that the assessment questions include algebraic “math” questions and questions in context. The answers to questions assessing this standard should be the actual function they are building, as other standards allow students to identify and interpret key features.</p> <p>Example: Build polynomial functions with a double root at -2 and another root at 5. <i>Note: This example should be connected to NC.M3.F-BF.3, as students should understand which transformations functions do not change the zeros of the functions. This could also be connected to NC.M3.N-CN.9, as students should understand how to create multiple equations that could be solved with the same roots.</i></p> <p>Example: The population of a certain animal being researched by environmentalists has been decreasing substantially. Biologists tracking the species have determined the following data set to represent the remaining animals:</p> <table><tr><td>Year</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td></tr><tr><td>Pop.</td><td>40,000</td><td>30,000</td><td>22,500</td><td>16,875</td><td>12,656</td></tr></table> <p>Assuming the population continues at the same rate, what function would represent the population $f(x)$ in year x, assuming x is the number of years after the year 2000?</p>				Year	2010	2011	2012	2013	2014	Pop.	40,000	30,000	22,500	16,875	12,656
Year	2010	2011	2012	2013	2014													
Pop.	40,000	30,000	22,500	16,875	12,656													

Mastering the Standard

Comprehending the Standard

Assessing for Understanding

Example: Build a polynomial function that could represent the following graph, and explain how each characteristic you could see on the graph helped you build the function.



Instructional Resources

Tasks

[Cockroaches](#) (2016 Just In Time Virtual Session)

Additional Resources

[Polynomial Functions Unit](#) Classroom Task: 3.1 (Mathematics Visions Project)
[Truncated Graph](#)

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Functions – Building Functions

NC.M3.F-BF.1b

Build a function that models a relationship between two quantities.

Write a function that describes a relationship between two quantities.

- b. Build a new function, in terms of a context, by combining standard function types using arithmetic operations.

Concepts and Skills		The Standards for Mathematical Practices	
Pre-requisite		Connections	
<ul style="list-style-type: none">Build new function by combine linear, quadratic and exponential functions (NC.M1.F-BF.1b)Operations with polynomials (NC.M1.A-APR.1)Operations with rational expressions (NC.M3.A-APR.7a, NC.M3.A-APR.7b)		<i>The following SMPs can be highlighted for this standard.</i> 1 – Make sense of problems and persevere in solving them 4 – Model with mathematics	
Connections		Disciplinary Literacy	
<ul style="list-style-type: none">Create equation to graph and solve (NC.M3.A-CED.1, NC.M3.A-CED.2)Analyze the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7)		Students should be able to justify new function and discuss how the new function fits the context.	

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>This standard asks students to combine standard function types by addition, subtraction, and multiplication. In Math 3, we are NOT required to include composition, although it could be a valuable extension.</p> <p>The key concept for teaching this standard is a review of adding and subtracting expressions (including combining like terms) and multiplying expressions (distributing polynomials and exponent rules).</p>	<p>In assessing this standard, students will need to perform the operations and determine from a context which operation is appropriate. The functions that students need to combine should be given in problems, but the operation can be determined from context if necessary.</p> <p>Example: Last year, army engineers modeled the function of a bullet fired by a United States soldier from a certain weapon. The function $f(x) = -16x^2 + 200x + 4$ modeled the path of the bullet. This year, the soldiers were supplied with more powerful guns that changed the path of the bullet from higher ground by adding the function $g(x) = 300x + 20$. What function models the path of the new bullet?</p> <p>Example: Consider the functions: $f(x) = 4x + 9$ and $g(x) = -2x - 4$</p> <p>a) Evaluate $f(-3)$.</p> <p>b) Evaluate $g(-3)$.</p> <p>c) Add $f(x) + g(x)$.</p> <p>d) Evaluate $(f + g)(-3)$.</p> <p>e) What do you notice? What properties have you learned that explain your answer?</p> <p>Example: A cup of coffee is initially at a temperature of 93° F. The difference between its temperature and the room temperature of 68° F decreases by 9% each minute. Write a function describing the temperature of the coffee as a function of time.</p> <p>Example: The length of the base of a rectangular prism is given as $x + 4$, and the width of the base is $x + 2$. The height of the rectangular prism is three more than two times the length. Build a function to model the volume of the rectangular prism.</p>

Mastering the Standard

Example: You are throwing a birthday party at a bowling alley for your little brother. It costs \$75 to rent a room, plus an additional cost of \$4.50 per child. Write a model that gives the average cost per child.

Example: Information from an analysis of the past several years has allowed the owners of local pool to develop the following function rules for the number of customers $n(x)$ and total profit $p(x)$ based on the entrance fee to the pool x . Write an algebraic rule for the profit per customer in terms of the entrance fee x .

$$n(x) = 100 - 4x$$

$$p(x) = -3x^2 + 70x - 2$$

Instructional Resources

Tasks

Additional Resources

[Polynomial Functions Unit](#) Classroom Task: 3.1, 3.4 (Mathematics Visions Project)

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Functions – Building Functions

NC.M3.F-BF.3

Build new functions from existing functions.

Extend an understanding of the effects on the graphical and tabular representations of a function when replacing $f(x)$ with $k \cdot f(x)$, $f(x) + k$, $f(x + k)$ to include $f(k \cdot x)$ for specific values of k (both positive and negative).

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Understand the effects of transformations on functions (NC.M2.F-BF.3) Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b)
Connections
<ul style="list-style-type: none"> Analyze and compare the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) Build polynomial and exponential functions from a graph, description, or ordered pairs (NC.M3.F-BF.1a)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>3 – Construct a viable argument and critique the reasoning of other</p>
Disciplinary Literacy
<p>Students should be able to explain why $f(x + k)$ moves the graph of the function left or right depending on the value of k.</p>

Mastering the Standard

Comprehending the Standard

Students learned the translation and dilation rules in Math 2 with regard to linear, quadratic, square root, and inverse variation functions. In Math 3, we apply these rules to functions in general.

Students should conceptually understand the transformations of functions and refrain from blindly memorizing patterns of functions. Students should be able to explain why $f(x + k)$ moves the graph of the function left or right depending on the value of k .

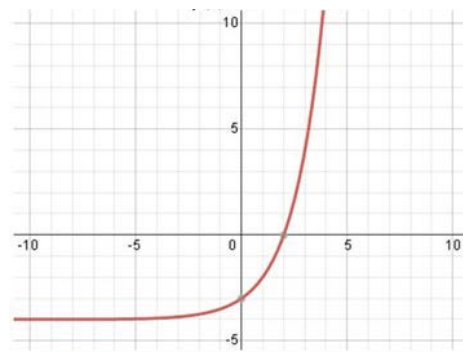
Note: Phase shifts and transformations of trigonometric functions are NOT required in Math 3. Those will be covered in the fourth math course.

Assessing for Understanding

In demonstrating their understanding, students must be able to relate the algebraic equations, graphs, and tabular representations (ordered pairs) as functions are transformed. Appropriate questions will ask students to identify and explain these transformations.

Example: The graph of $f(x)$ and the equation of $g(x)$ are shown below. Which has a higher y-intercept? Explain your answer.

$f(x)$:



$$g(x) = 2^x - 7$$

Example: Use the table below to identify the transformations and write the equation of the absolute value function $f(x)$.

x	-6	-5	-4	-3	-2
f(x)	3	1	-1	1	3

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
	<p>Example: Why does $g(x) = \frac{1}{x-3}$ shift to the right three units from the rational function $f(x) = \frac{1}{x}$?</p> <p>Example: Suppose $f(x) = x^2$ where x can be any real number.</p> <ol style="list-style-type: none"> Sketch a graph of the function f. Sketch a graph of the function g given by $g(x) = f(x) + 2$. How do the graphs of f and g compare? Why? Sketch a graph of the function h given by $h(x) = -2f(x)$. How do the graphs of f and h compare? Why? Sketch a graph of the function p given by $p(x) = f(x + 2)$. How do the graphs of f and p compare? Why? <p>For commentary go to https://www.illustrativemathematics.org/content-standards/HSF/BF/B/3/tasks/741.</p>

Instructional Resources	
Tasks	Additional Resources
Transforming the Graph of a Function (Illustrative Mathematics)	Rational Functions Unit Classroom Task: 4.2 (Mathematics Visions Project)

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Functions – Building Functions

NC.M3.F-BF.4a

Build new functions from existing functions.

Find an inverse function.

- a. Understand the inverse relationship between exponential and logarithmic, quadratic and square root, and linear to linear functions and use this relationship to solve problems using tables, graphs, and equations.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Analyze the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7)
Connections <ul style="list-style-type: none"> The existence of an inverse function and representing it (NC.M3.F-BF.4b, NC.M3.F-BF.4c)

The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>6 – Attend to precision</p>
Disciplinary Literacy <p><i>New Vocabulary: inverse function</i></p> <p>Students should be able to discuss the relationship between inverse operations and inverse functions.</p>

Mastering the Standard

Comprehending the Standard

Students have used inverse operations to solve equations in previous math courses, but this is the first time students are introduced to the concept of an inverse function. All of the F-BF.4 standards relate, but the progression of understanding the relationship, determining if an inverse exists, and solving for the inverse through the F-BF.4a, F-BF.4b, and F-BF.4c will enhance understanding.

For this part of the standard, the main concept students must understand is that an inverse function switches the input and output (x and y) for every point in the function. It is important to connect this concept to the reflection of one function, $f(x)$, across the line of symmetry $y = x$, to create the inverse function, $g(x)$. In Math 3, we are limiting the functions to linear, quadratic, square root, exponential, and logarithmic.

Students must also understand the common notation f^{-1} to represent inverse functions.

Students, while having worked with quadratic and square root functions, may not have explored all aspects of the inverse relationship.

Students started work with exponential functions in NC Math 1, and have not been exposed to logarithms before this course.

When speaking of inverse relationships, it is important for students to understand and communicate the reasoning for finding an inverse function. This can often be accomplished by considering the independent and dependent variables, the context of the problem, and a chosen solution pathway.

Assessing for Understanding

Students should first start by exploring the relationships between inverse functions.

Example: Complete the following tables for the given functions. Which are inverses? Explain your answer.

$$f(x) = \frac{1}{10}x$$

X	0	1	2	3	4
f(x)					

$$g(x) = 10^x$$

X	0	1	2	3	4
f(x)					

$$h(x) = 10x$$

X	0	1	2	3	4
f(x)					

$$j(x) = \log_{10} x$$

X	1	100	1,000	10,000	100,000
f(x)					

Mastering the Standard

Comprehending the Standard

Assessing for Understanding

As students are solving problems using inverses, common formulas can help students understand this inverse relationship (Celsius/Fahrenheit conversions, geometry formulas, interest formulas). To understand the concept of an inverse function, students should be asked to explain the input as a function of the output and how this affects the values.

Example: The area of a square can be described as a function of the length of a side, $A(s) = s^2$.

What is the area of a square with side length 5 cm?

What is the length of a side of a square with an area 25 cm²?

What relationship do a function of area given a side length and a function of side length given the area share? How do you know?

Use this relationship to solve for the length of a side of a square with an area of 200 cm².

Example: Complete the table to write the inverse for the following function. Is the inverse a function? Explain your answer.

x	1	2	3	4	5
f(x)	2	4	9	4	12

x					
f ⁻¹ (x)					

Instructional Resources

Tasks

[Water Tower Task](#) (2016 Summer Information Session)

[Cockroaches](#) (2016 Just in Time Virtual Session)

Additional Resources

[Inverse Graphing Discovery](#)

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Functions – Building Functions

NC.M3.F-BF.4b

Build new functions from existing functions.

Find an inverse function.

- b. Determine if an inverse function exists by analyzing tables, graphs, and equations.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Analyze the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7) Understand inverse relationships (NC.M3.F-BF.4a)
Connections
<ul style="list-style-type: none"> Represent inverse functions (NC.M3.F-BF.4c)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>3 – Construct viable arguments and critique the reasoning of others</p>
Disciplinary Literacy
<p>New Vocabulary: <i>inverse function</i></p> <p>Students should be able to discuss the reasoning in needing a restricted domain.</p>

Mastering the Standard

Comprehending the Standard

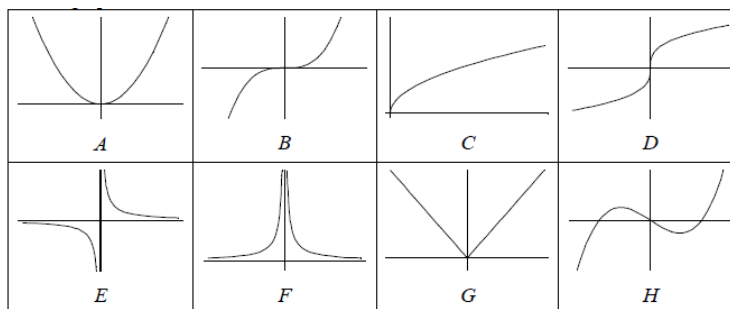
In Math 1, students learned to determine if a relation is a function by analyzing tables, equations, and graphs. In Math 3, students need to determine if a function is invertible and on what domain.

This part of the standard is not limited by function type. This means that students should be able to determine if any function or a portion of the function has an inverse function from different representations.

Assessing for Understanding

The standard states that students must determine if an inverse function exists, so presenting graphs, tables, and equations are all appropriate representations for students to analyze. Additionally, especially for quadratic functions, students must be able to determine the appropriate domain for a function to have an inverse.

Example: Which of the following functions have inverse functions? For those that do not have inverse functions as a whole, divide the graph into sections that do have inverse functions.



Example: Use a table of $f(x) = 3x^2 - 18x + 5$ to determine possible domains on which $f^{-1}(x)$ is a function.

Example: Which of the following equations have an inverse function? How do you know, from the table and graph? For any that do not, how can we limit the domain of the function to ensure that it has an inverse?

- $f(x) = 2x$
- $f(x) = x^2$
- $f(x) = 2^x$

Mastering the Standard

Comprehending the Standard

Assessing for Understanding

Example: Determine which function(s) have an inverse function from the tables below. Provide a reason if an inverse function does not exist.

$g(x)$	x
-2	9
-1	3
0	1
1	3
2	9
3	19

$h(x)$	x
-2	-12
-1	-9
0	-6
1	-3
2	0
3	3

$j(x)$	x
-2	4
-1	2
0	1
1	0.5
2	0.25
3	0.125

$k(x)$	x
-2	5
-1	3
0	1
1	-1
2	1
3	3

Example: Given the table below, tell if an inverse function exists and if it does, graph the inverse.

x	0	1	2	3	4
$f(x)$	0.25	0.5	1	2	4

Example: For the function represented in the table on the right, would an inverse function exist? Explain.

x	y
-2	2
-1	-1
0	-2
1	-1
2	2
3	7

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Functions – Building Functions

NC.M3.F-BF.4c

Build new functions from existing functions.

Find an inverse function.

- c. If an inverse function exists for a linear, quadratic and/or exponential function, f , represent the inverse function, f^{-1} , with a table, graph, or equation and use it to solve problems in terms of a context.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Interpret parts of an expression in context (NC.M3.A-SSE.1a, NC.M3.A-SSE.1b) Analyze the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7) Understand inverse relationships and determine if an inverse exist (NC.M3.F-BF.4a, NC.M3.F-BF.4b) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 1 – Make sense of problems and persevere in solving them
Connections <ul style="list-style-type: none"> Use logarithms to expression solutions to exponential functions (NC.M3.F-LE.4) 	Disciplinary Literacy <i>New Vocabulary: inverse function</i> Students should discuss which representation (tabular, graphical, or symbolic) is the most efficient to solve a particular problem.

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
<p>Once students understand the concept of a function that has an inverse, they can begin solving for the inverse functions. The idea of reversing the input and output (x and y) is central to solving for an inverse algebraically, and it should also be emphasized on the graph (reflection over the $y = x$ line) and table.</p> <p>It is important to note; the algebraic approach can be complex in many cases. Often, tables and graphs can be used to solve problems in a more efficient and student friendly manner.</p> <p>In Math 3, the functions are limited to linear, quadratic, and exponential. For quadratics, it must be emphasized that we have the equation in a form we can solve for the input variable, so this can be an appropriate concept in which to review completing the square and vertex form, from Math 2.</p>	<p>Most assessment items for this standard will ask students to solve for an inverse using a graph or equation. Real-world context exists with common conversion formulas, area/volume formulas, and interest formulas.</p> <p>Example: Graph the inverse of $f(x) = -\frac{3}{2}x - 3$. How does $f^{-1}(x)$ relate to $f(x)$?</p> <p>Example: Find the inverse of the function $g(x) = 2^x$ and demonstrate it as the inverse using input – output pairs.</p> <p>Example: Let $h(x) = x^3$. Find the inverse function.</p> <p>Example: Let $f(x) = x^2 + 7x + 9$. Does an inverse function exist for the entire domain of the function? Find the inverse of this function.</p>

Instructional Resources

Tasks	Additional Resources
Cockroaches (2016 Just In Time Virtual Session)	

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Functions – Linear, Quadratic, and Exponential Models

NC.M3.F-LE.3

Construct and compare linear and exponential models and solve problems.

Compare the end behavior of functions using their rates of change over intervals of the same length to show that a quantity increasing exponentially eventually exceeds a quantity increasing as a polynomial function.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Calculate and interpret the average rate of change (NC.F-IF.6) Compare the end behavior of linear, exponential and quadratic functions (NC.M1.F-LE.3) Analyze and compare the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.7, NC.M3.F-IF.9)
Connections

The Standards for Mathematical Practices
Connections <i>The following SMPs can be highlighted for this standard.</i> 4 – Model with mathematics
Disciplinary Literacy Students should be able to discuss the rate of change for each function type as the value of the domain increases.

Mastering the Standard

Comprehending the Standard	Assessing for Understanding																		
<p>This standard is included in Math 1 and 3. In previous courses, students studied linear, exponential, and quadratic models. In Math 3, polynomial functions are included.</p> <p><i>For Example:</i> For the functions $f(x) = x^3$ and $g(x) = 3^x$, which function has a greater value at:</p> <p>a) $x = 0.5$ b) $x = 1$ c) $x = 1.5$ d) $x = 2$ e) $x = 2.5$ f) $x = 3$ g) $x = 3.5$ h) $x = 4$</p>	<p>Students must demonstrate that they understand how exponential functions ultimately increase at a greater rate than polynomial functions when considering the end behavior – namely, the rate of change is greater for an exponential function as the function increases to infinity.</p> <p>Example: Using technology, determine the average rate of change of the following functions for intervals of their domains in the table.</p> <table><tr><th>Functions</th><th>Average rate of change $0 \leq x \leq 10$</th><th>Average rate of change $10 \leq x \leq 20$</th><th>Average rate of change $20 \leq x \leq 30$</th><th>Average rate of change $30 \leq x \leq 40$</th><th>Average rate of change $40 \leq x \leq 50$</th></tr><tr><td>$f(x) = x^3$</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>$f(x) = 1.3^x$</td><td></td><td></td><td></td><td></td><td></td></tr></table> <p>a) When does the average rate of change of the exponential function exceed the average rate of change of the polynomial function?</p> <p>b) Using a graphing technology, graph both functions. How do the average rates of change in your table relate to what you see on the graph?</p> <p>c) In your graphing technology, change the first function to $f(x) = x^4$ and adjust the settings to see where the functions intersect. What do you notice about the rates of change interpreted from the graph?</p> <p>d) Make a hypothesis about the rates of change about polynomial and exponential function. Try other values for the exponent of the polynomial function to support your hypothesis.</p>	Functions	Average rate of change $0 \leq x \leq 10$	Average rate of change $10 \leq x \leq 20$	Average rate of change $20 \leq x \leq 30$	Average rate of change $30 \leq x \leq 40$	Average rate of change $40 \leq x \leq 50$	$f(x) = x^3$						$f(x) = 1.3^x$					
Functions	Average rate of change $0 \leq x \leq 10$	Average rate of change $10 \leq x \leq 20$	Average rate of change $20 \leq x \leq 30$	Average rate of change $30 \leq x \leq 40$	Average rate of change $40 \leq x \leq 50$														
$f(x) = x^3$																			
$f(x) = 1.3^x$																			

Instructional Resources

Tasks	Additional Resources
	Polynomial Functions Unit Classroom Task: 3.2 (Mathematics Visions Project)

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Functions – Linear, Quadratic, and Exponential Models

NC.M3.F-LE.4

Construct and compare linear and exponential models and solve problems.

Use logarithms to express the solution to $ab^{ct} = d$ where a , b , c , and d are numbers and evaluate the logarithm using technology.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Create equation to graph and solve (NC.M3.A-CED.1, NC.M3.A-CED.2) Justify a solution method and each step in the solving process (NC.M3.A-REI.1) Understand the inverse relationship between functions (NC.M3.F-BF.4a) Represent inverse functions (NC.M3.F-BF.4c)
Connections

The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>4 – Model with mathematics</p>
Disciplinary Literacy <p><i>New Vocabulary: logarithm</i></p> <p>Students should be able to discuss logarithms as the inverse function of an exponential function.</p>

Mastering the Standard	
Comprehending the Standard <p>Building on the inverse relationship students conceptualized for exponents and logarithms in F-BF.4, students will rewrite exponents in logarithmic form and use it to solve equations, both algebraically and in the context of word problems.</p> <p>Students will also need to be able to determine numerical approximations for the logarithms using technology.</p> <p><i>For Example:</i> Rewrite the following in logarithmic form. Then, evaluate the logarithms using technology.</p> <p>a) $10^x = 1000$ b) $3^x = 1000$</p> <p>Students should use the relationship between exponential and logarithmic functions to solve problems.</p> $b^c = d \leftrightarrow \log_b d = c$ <p>a. Students can use substitution to reveal another relationship that can be used to solve the original problem. For example:</p> $5^{x+3} = 372$ <p>The goal is to rewrite each expression so they both have the same base. In this case, we are using 10.</p> <p>Starting with the expression on the left, $5 = 10^m$, rewrite using logarithmic form. We see that $m = \log_{10} 5$. Using substitution, this means that $5 = 10^{\log_{10} 5}$.</p> <p>Using the same procedure with the expression on the right we get, $372 = 10^{\log_{10} 372}$. We can now substitute these back into the original equation.</p> $5^{x+3} = 372$	Assessing for Understanding <p>Students must demonstrate the ability to solve exponential equations for an exponent variable using logarithms, and they should be able to express their answer in logarithmic form and using a decimal approximation.</p> <p>Example: Consider the following investments.</p> <ol style="list-style-type: none"> A parent invests \$2,000 at a 5% interest rate to help his daughter save for college. How long will it take his money to double? (Show your equation and the work.) A banker invests \$50,000 at a 5% interest rate to make money for Wells Fargo. How long will it take the bank's money to double? (Show your equation and the work.) What do you notice about the answers? Based on your work, why is that the case?

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
$(10^{\log_{10} 5})^{x+3} = 10^{\log_{10} 372}$ <p>Because this is an equation and both sides of the equation are base 10, the exponents must be equal. This reveals a new equation that can be used to solve for x.</p> $(\log_{10} 5)(x + 3) = \log_{10} 372$ $x = \frac{\log_{10} 372}{\log_{10} 5} - 3$ $x \approx .6776$ <p>b. Students are expected to rewrite an exponential equation into logarithmic form to find or approximate a solution. For example:</p> $5^{x+3} = 372$ $\log_5 372 = x + 3$ $\log_5 372 - 3 = x$ $x \approx .6776$ <p>Students are not expected to know or use the properties of logarithms, e, or natural logs to solve problems. These can be extension topics but are beyond the scope of the NC Math 3 standards.</p>	

Instructional Resources

Tasks	Additional Resources
Cockroaches (2016 Just In Time Virtual Session)	

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Functions – Trigonometric Functions

NC.M3.F-TF.1

Extend the domain of trigonometric functions using the unit circle.

Understand radian measure of an angle as:

- The ratio of the length of an arc on a circle subtended by the angle to its radius.
- A dimensionless measure of length defined by the quotient of arc length and radius that is a real number.
- The domain for trigonometric functions.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> • Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1)
Connections
<ul style="list-style-type: none"> • Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1) • Define radian measure (NC.M3.G-C.5)

The Standards for Mathematical Practices
Connections
<i>The following SMPs can be highlighted for this standard.</i>
Disciplinary Literacy
<i>New Vocabulary: arc length</i> Students should be able to discuss the relationship between degrees and radians.

Mastering the Standard	
Comprehending the Standard To build the understanding of radian measure, students should first become familiar with degree measure. In ancient times, when discussing angle measure, it was realized that the best way to describe angle measure was through a ratio. It was decided based on a different numbering system that they would divide a circle into 360 sectors and each of the sectors would measure 1 degree. The division of the circle into 360 sectors not only divided the angle, but also divided the arc of the circle as well. (Hence the measure of the central angle is the same as the measure of the intercepted arc.) This means that a measure of 42° is $42 \left(\frac{1}{360}\right)$ of a circle or 42 divisions of the 360 divisions. In modern times, as science and mathematics knowledge increased, the decision to divide a circle into 360 parts is arbitrary and less precise. This led to the development of radian measures. In this process, a ratio is still used, however the circle is not divided into parts but is described in the ratio of the circumference to the radius. Here is a good resource to understand radian measure: Find radian measure by dividing arc length by radius (Learn Zillion) By discovery (using string, rolling a can, etc.), students can determine that it takes just over 6 radii to create the circumference of a circle, and the teacher can relate that to 2π .	Assessing for Understanding In mastering this standard, students will need to demonstrate an understanding of radian angle measure and applying the arc length formula (Arc Length = Radius • Radian Measure) to solve for any missing measure, both using basic measures and in the context of word problems. The following examples are from NC.M3.G-C.5 but require the understanding of this standard. Example: An angle with a measure of 4 radians intercepts an arc with a length of 18 ft. What is the length of the radius of the circle? Example: The minute hand on the clock at the City Hall clock in Stratford measures 2.2 meters from the tip to the axle. a) Through what radian angle measure does the minute hand pass between 7:07 a.m. and 7:43 a.m.? b) What distance does the tip of the minute hand travel during this period?

Instructional Resources	
Tasks	Additional Resources
	Converting Degrees and Radians Trigonometric Functions Unit Classroom Task: 6.6, 6.7, 6.8, 6.9 (Mathematics Visions Project) expectations

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Functions – Trigonometric Functions

NC.M3.F-TF.2a

Extend the domain of trigonometric functions using the unit circle.

Build an understanding of trigonometric functions by using tables, graphs and technology to represent the cosine and sine functions.

- Interpret the sine function as the relationship between the radian measure of an angle formed by the horizontal axis and a terminal ray on the unit circle and its y coordinate.

Concepts and Skills

Pre-requisite

- Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1)
- Understand radian measure (NC.M3.F-TF.1)

Connections

- Analyze and compare the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9)

The Standards for Mathematical Practices

Connections

The following SMPs can be highlighted for this standard.

2 – Reason abstractly and quantitatively

Disciplinary Literacy

Students should describe the relationship between sine represented on a unit circle and graphical representation of the sine function.

Mastering the Standard

Comprehending the Standard

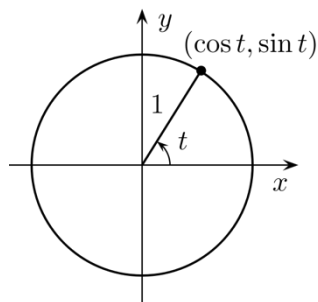
Students will be introduced to the unit circle and angle measures on the coordinate plane in Math 3 as a way to relate the sine and cosine ratios to the coordinates and the plane.

A unit circle is used to develop the concepts of this standard to simplify the picture for students. In Math 3, students are only introduced to the trigonometric functions.

This standard builds upon previous understanding of the trig ratios in right triangles.

$\sin \theta$ is the unit rate produced by the ratio of the length of the opposite side to the length of the hypotenuse.

$$\sin \theta = \frac{\text{length of opposite side}}{\text{length of hypotenuse}}$$



Since we are working within a unit circle, and the hypotenuse is the radius of the unit circle, so the length of the hypotenuse is 1 unit. This means that $\sin \theta = \frac{\text{length of opposite side}}{1}$, so with the unit circle, $\sin \theta$ is the length of the opposite side. This means that the height of the triangle, which is the y-coordinate of the vertex on the circle, is $\sin \theta$.

The focus of this standard is on the relationship between the changing angle of the sine function and the value of the sine ratio. This should allow students to move from the unit circle to graphing the relationship on a coordinate plane in which the independent variable is the angle measure and the

Assessing for Understanding

Students apply reasoning to their knowledge of the relationship between angles and the sides of right triangles.

Example: A stink bug has crawled into a box fan and sits on the tip of the blade of the fan as seen below. The fan starts to turn slowly due to a breeze in the room.

- Create a function and a graph that describes its change in height from its original position based on the angle of the blade from its original position.
- What is the height of the stink bug when the blade has rotated 2 radians? $\frac{11\pi}{6}$ radians?
- How much has the blade rotated when the stink bug's height is $-\frac{3}{4}$ feet? Can there be more than one answer?



Mastering the Standard

Comprehending the Standard	Assessing for Understanding
<p>dependent variable is the value of the sine ratio (the y-coordinate from the unit circle). This is a strong connection to NC.M3.F-IF.1.</p> <p>In general, from the unit circle, students should see that as the angle is near zero, the ratio of the length of the opposite side to the length of the hypotenuse is also near zero. As the angle starts to increase and approaches 90° or $\frac{\pi}{2}$, the value of the sine ratio approaches 1. This pattern continues around the unit circle and eventually demonstrates the periodicity of the sine function.</p> <p>An in depth teaching of the unit circle, tangent and reciprocal ratios, coterminal angles, specific coordinates and the Pythagorean Identity are NOT appropriate for Math 3, as they will be covered in depth in the fourth math course.</p> <p>Students should understand these relationships in degree and radian angle measure.</p>	

Instructional Resources

Tasks	Additional Resources
	<p>Trigonometric Functions Unit Classroom Task: 6.3, 6.6, 6.7, 6.8, 6.9 (Mathematics Visions Project)</p>

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Functions – Trigonometric Functions

NC.M3.F-TF.2b

Extend the domain of trigonometric functions using the unit circle.

Build an understanding of trigonometric functions by using tables, graphs and technology to represent the cosine and sine functions.

- Interpret the cosine function as the relationship between the radian measure of an angle formed by the horizontal axis and a terminal ray on the unit circle and its x coordinate.

Concepts and Skills

Pre-requisite

- Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1)
- Understand radian measure (NC.M3.F-TF.1)

Connections

- Analyze and compare the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9)

The Standards for Mathematical Practices

Connections

The following SMPs can be highlighted for this standard.

- Reason abstractly and quantitatively

Disciplinary Literacy

Students should describe the relationship between cosine represented on a unit circle and graphical representation of the cosine function.

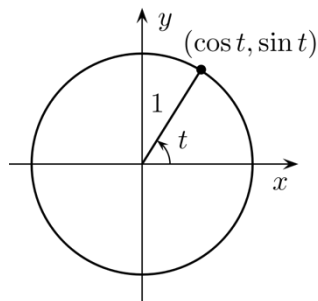
Mastering the Standard

Comprehending the Standard

Students will be introduced to the unit circle and angle measures on the coordinate plan in Math 3 as a way to relate the sine and cosine ratios to the coordinates and the plane.

A unit circle is used to develop the concepts of this standard to simplify the picture for students. In Math 3, students are only introduced to the trigonometric functions. This standard builds upon previous understanding of the trig relationship in right triangle. $\cos \theta$ is the unit rate produced by the ratio of the length of the adjacent side to the length of the hypotenuse.

$$\cos \theta = \frac{\text{length of adjacent side}}{\text{length of hypotenuse}}$$



Since we are working within a unit circle, and the hypotenuse is the radius of the unit circle, so the length of the hypotenuse is 1 unit. This means that $\cos \theta = \frac{\text{length of adjacent side}}{1}$, so with the unit circle, $\cos \theta$ is the length of the adjacent side. This means that the base of the triangle, which is the x -coordinate of the vertex on the circle, is $\cos \theta$. The focus of this standard is on the relationship between the changing angle of the cosine function

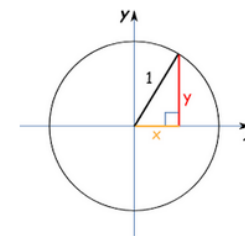
and the value of the cosine ratio. This should allow students to move from the unit circle to graphing the relationship on a coordinate plane in which the independent

Assessing for Understanding

Students apply reasoning to their knowledge of the relationship between angles and the sides of right triangles.

Example: Using the unit circle and segments below:

- Why is the cosine value of the reference angle equal to x ?
- For $90^\circ < \theta < 270^\circ$, why is the cosine value negative?
- Why is the range of the cosine function $-1 \leq y \leq 1$?
- Will the cosine value ever equal the sine value? Why or why not?



Mastering the Standard

Comprehending the Standard

variable is the angle measure and the dependent variable is the value of the cosine ratio (the x -coordinate from the unit circle). This is a strong connection to NC.M3.F-IF.1. From the unit circle, students should see that as the angle is near zero, the ratio of the length of the opposite side to the length of the hypotenuse is also near 1. As the angle starts to increase and approaches 90° or $\frac{\pi}{2}$, the value of the cosine ratio approaches 0. This pattern continues around the unit circle and eventually demonstrates the periodicity of the cosine function.

An in depth teaching of the unit circle, tangent and reciprocal ratios, coterminal angles, specific coordinates and the Pythagorean Identity are NOT appropriate for Math 3, as they will be covered in depth in the fourth math course.

Students should understand these relationships in degree and radian angle measure.

As the angle changes, sine represents the change in the y -coordinate (height of the triangle) on the unit circle, cosine represents the change in the x -coordinate (length of the base of the unit circle).

Students should be able to not only see the relationship between the functions represented on a unit circle and the graphical representation on the coordinate plane, but should understand the relationship between the sine and cosine functions.

Assessing for Understanding

Instructional Resources

Tasks

Additional Resources

[Trigonometric Functions Unit](#) Classroom Task: 6.3, 6.6, 6.7, 6.8, 6.9 (Mathematics Visions Project) **NEW**

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Functions – Trigonometric Functions

NC.M3.F-TF.5

Model periodic phenomena with trigonometric functions.

Use technology to investigate the parameters, a , b , and h of a sine function, $f(x) = a \cdot \sin(b \cdot x) + h$, to represent periodic phenomena and interpret key features in terms of a context.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Interpret parts of an expression in context (NC.M3.A-SSE.1a) Recognize that trig ratios are functions of angle measure (NC.M3.F-IF.1) Understand radian measure (NC.M3.F-TF.1) Build an understanding of trig functions (NC.M3.F-TF.2a, NC.M3.F-TF.2b) 	Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>3 – Construct viable arguments and critique the reasoning of others</p>
Connections <ul style="list-style-type: none"> Analyze and compare the key features of functions for tables, graphs, descriptions and symbolic form (NC.M3.F-IF.4, NC.M3.F-IF.7, NC.M3.F-IF.9) 	Disciplinary Literacy <p><i>New Vocabulary: period, amplitude</i></p> <p>Students should be able to discuss how changing the parameters effects the different representations.</p>

Mastering the Standard

Comprehending the Standard

It is important to not overreach with this standard. In Math 3, students are just being introduced to the concepts of the sine function and the effects of the various representations by changing parameters.

As the phrase at the beginning of the standards states, students should use technology to investigate these changes.

There are several excellent online resources to investigate the change in parameters of trig functions. For some of these resources, you may need to create an account. Some of these resources are listed below. Some of the resources explore horizontal phase shift, which is not part of this standard.

Phase shifts and complicated trigonometric functions are not part of the standards for Math 3, as they will be covered in depth in the fourth math course. This is an introduction to the concept of a periodic graph through learning the sine function.

Assessing for Understanding

Students should be able to explain how the change in parameters effects the various representations and interpret them in a context.

Example: The following function describes the stock price for Facebook where m stands for the number of months since May 2012. Use technology to graph and create tables as needed.

$$f(m) = -11 \sin\left(\frac{2\pi}{4}m\right) + 38$$

- Interpret the 38 in the context of the problem.
- What does -11 mean in context of the problem and what is the significance of 11 being negative?
- How long does it take for the pattern to start repeating?
- During which months would you want to buy and sell stock in Facebook?

Instructional Resources

Tasks

[Representing Trigonometric Functions](#)

Additional Resources

[Graphing the Sine Function using Amplitude, Period, and Vertical Translation](#) (Desmos.com)

[A visual explanation of the characteristics of the Sine Function](#) (Geogebra.org)

[Trigonometric Functions Unit](#) Classroom Task: 6.1, 6.2, 6.4, 6.10, 6.11, 6.12 (Mathematics Visions Project)

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Geometry

NC Math 1	NC Math 2	NC Math 3
Analytic & Euclidean		
Focus on coordinate geometry <ul style="list-style-type: none"> Distance on the coordinate plane Midpoint of line segments Slopes of parallel and perpendicular lines Prove geometric theorems algebraically 	Focus on triangles <ul style="list-style-type: none"> Congruence Similarity Right triangle trigonometry <ul style="list-style-type: none"> Special right triangles 	Focus on circles and continuing the work with triangles <ul style="list-style-type: none"> Introduce the concept of radian Angles and segments in circles Centers of triangles Parallelograms
A Progression of Learning		
Integration of Algebra and Geometry <ul style="list-style-type: none"> Building off of what students know from 5th – 8th grade with work in the coordinate plane, the Pythagorean theorem and functions. Students will integrate the work of algebra and functions to prove geometric theorems algebraically. Algebraic reasoning as a means of proof will help students to build a foundation to prepare them for further work with geometric proofs. 	Geometric proof and SMP3 <ul style="list-style-type: none"> An extension of transformational geometry concepts, lines, angles, and triangles from 7th and 8th grade mathematics. Connecting proportional reasoning from 7th grade to work with right triangle trigonometry. Students should use geometric reasoning to prove theorems related to lines, angles, and triangles. <p><i>It is important to note that proofs here are not limited to the traditional two-column proof. Paragraph, flow proofs and other forms of argumentation should be encouraged.</i></p>	Geometric Modeling <ul style="list-style-type: none"> Connecting analytic geometry, algebra, functions, and geometric measurement to modeling. Building from the study of triangles in Math 2, students will verify the properties of the centers of triangles and parallelograms.

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Geometry – Congruence

NC.M3.G-CO.10

Prove geometric theorems.

Verify experimentally properties of the centers of triangles (centroid, incenter, and circumcenter).

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Use triangle congruence to prove theorems about lines, angles, and segments in triangles (NC.M2.G-CO.10) 	Connections <p>The following SMPs can be highlighted for this standard.</p> <p>3 – Construct viable arguments and critique the reasoning of others</p> <p>5 – Use appropriate tools strategically</p>
Connections <ul style="list-style-type: none"> Understand and apply theorems about circles (NC.M3.G-C.2) 	Disciplinary Literacy <p>New Vocabulary: centroid, incenter, circumcenter</p>

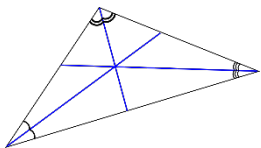
Mastering the Standard

Comprehending the Standard

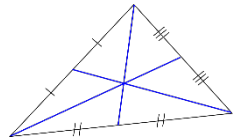
The goal is for students to be able to explore, make conjectures about the intersection of the different straight objects that produce the triangle centers, to justify why all three straight objects intersect at a common point, and why that point is an important feature of the triangle. The centers of triangles should be explored dynamically where students can discover them and their properties.

The centers of triangles are also known as points of concurrency for triangles. The three centers that are a focus for Math 3 are:

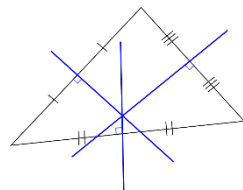
- Centroid – the point where the three medians of a triangle intersect



- Incenter – the point where the three angle bisectors of a triangle intersect



- Circumcenter – the point where the three perpendicular bisectors of the sides of a triangle intersect



Once defined, students should experiment to verify the following properties:

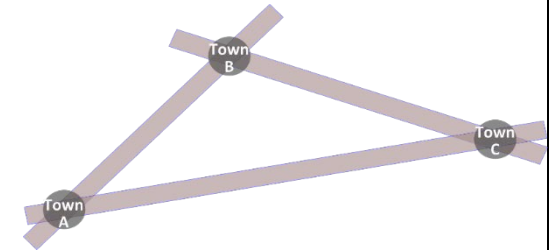
Assessing for Understanding

Students should demonstrate an understanding of the properties of the centers of triangles. The following task prompts students to consider the different centers, apply the properties to the context and make a decision about where to place the amphitheater.

Example:

A city plans to build an amphitheater and wants to locate it within easy access of the three largest towns in the area as shown on the map.

The developer must decide on the best location. The city will also have roads built for access directly to the towns or to the existing highways.



Describe how the developer might identify the location for the amphitheater. Choose one of the methods described and justify why this is the best location.

Possible student responses:

The circumcenter would place the amphitheater equidistant from the town. Roads would need to be built from the towns to the amphitheater. These roads would be the same distance.

The incenter would place the amphitheater from each road connecting the towns. Roads would need to be built from the existing roads to the amphitheater. These roads would be the same distance.

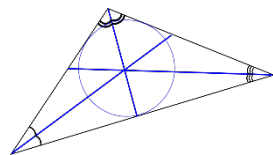
The centroid would place the amphitheater within the area surrounded by the three towns.

Mastering the Standard

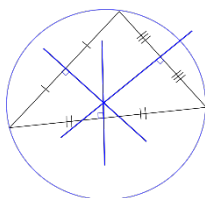
Comprehending the Standard

- The centroid
 - always falls within the triangle
 - is located two-thirds of the way along each median or partitions the median into a ratio of 2:1 with the longest segment nearest the vertex
 - divides the triangle into six triangles of equal area
 - is the center of gravity for the triangle.

- The incenter
 - always falls within the triangle
 - equidistant from the sides of the triangle
 - is the center of the circle that is inscribed by the triangle; largest circle that will fit inside a circle and touch all three sides



- The circumcenter
 - falls inside when the triangle is acute; outside when it is obtuse, and on the hypotenuse when it is right.
 - equidistant from the vertices of the triangle
 - is the center of the circle that circumscribes the triangle; the circle that passes through all three vertices



Assessing for Understanding

Instructional Resources

Tasks

[Inscribing and Circumscribing a Right Triangle](#)

Additional Resources

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Geometry – Congruence

NC.M3.G-CO.11

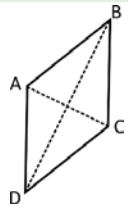
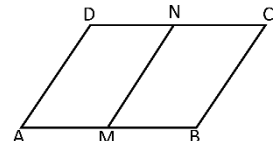
Prove geometric theorems.

Prove theorems about parallelograms.

- Opposite sides of a parallelogram are congruent.
- Opposite angles of a parallelogram are congruent.
- Diagonals of a parallelogram bisect each other.
- If the diagonals of a parallelogram are congruent, then the parallelogram is a rectangle.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> • Prove theorems about lines, angles, and segments for relationships in geometric figures (NC.M2.G-CO.9) • Use triangle congruence to prove theorems about lines, angles, and segments in triangles (NC.M2.G-CO.10) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 3 – Construct viable arguments and critique the reasoning of others 5 – Use appropriate tools strategically
Connections <ul style="list-style-type: none"> • Apply properties, definitions, and theorems of 2-D figures to prove geometric theorems (NC.M3.G-CO.14) • Apply geometric concepts in modeling situations (NC.M3.G-MG.1) 	Disciplinary Literacy

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
<p>This standard is connected to the standards NC.M2.G-CO.8 & 9. Students use the triangle congruence theorems and theorems about lines and angles to prove theorems about parallelograms. The standard includes four specific theorems; however, student experience should not be limited to only these four. Students should prove and apply the theorems listed. Application may include using the theorems to prove other theorems or to solve problems. (connect to NC.M3.G-CO.14 and NC.M3.G-MG.1).</p> <p>Given the definition of a parallelogram (a quadrilateral with both pairs of opposite sides parallel) all other properties of a parallelogram can be proven.</p> <p>Rectangles, rhombi, and squares are specific types of parallelograms. Consider including theorems that are specific to these such as:</p> <ul style="list-style-type: none"> • Diagonals of a rhombus are perpendicular bisectors. • Diagonals of a square are congruent and perpendicular bisectors. • Diagonals of a rhombus bisect the vertex angles. <p>Proof is not solely about knowing the theorems. The goal of proof is to further develop the ability to construct logical arguments. Students should develop both <i>flow</i> and <i>paragraph</i> proofs. The construction of logical arguments and the ability to explain their reasoning is what will be expected from students.</p>	<p>Students should apply proven theorems to prove additional theorems.</p> <div style="display: flex; align-items: flex-start;"> <div style="flex: 1;"> <p>Example: Given ABCD is a rhombus prove the diagonals \overline{BD} and \overline{AC} are perpendicular bisectors.</p> <p>Example: Suppose that ABCD is a parallelogram, and that M and N are the midpoints of \overline{AB} and \overline{CD} respectively. Prove that $\overline{MN} = \overline{AD}$ and that the line \overline{MN} is parallel to \overline{AD}.</p> </div> <div style="flex: 0.5; text-align: center;">  </div> </div> <div style="text-align: center; margin-top: 20px;">  </div>

Instructional Resources

Tasks	Additional Resources
	Properties of Quadrilaterals (Inside Mathematics)

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Geometry – Congruence

NC.M3.G-CO.14

Prove geometric theorems.

Apply properties, definitions, and theorems of two-dimensional figures to prove geometric theorems and solve problems.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Prove theorems about parallelograms (NC.M3.G-CO.11)
Connections
<ul style="list-style-type: none"> Use similarity to solve problems and to prove theorems about triangles (NC.M2.G-SRT.4) Understand and apply theorems about circles (NC.M3.G-C.2)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>1 – Make sense of problems and persevere in solving them</p> <p>3 – Construct viable arguments and critique the reasoning of others</p> <p>5 – Use appropriate tools strategically</p>
Disciplinary Literacy

Mastering the Standard

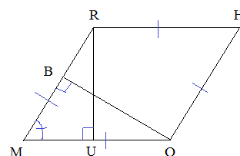
Comprehending the Standard

This standard is the application of the other two standards within this cluster NC.M3.G-CO.10 & 11. The other standards have students determine properties and prove theorems of figures. This standard is an application of those standards.

For this standard, instruction should provide students the opportunity to prove theorems for other two dimensional figures and to reason with figures to solve problems.

The geometric theorems may be for specific defined shapes. Consider including other quadrilaterals such as trapezoids and kites for students to explore. For example, prove the base angles of an isosceles trapezoid are congruent.

The geometric theorems may also be for a specific given figure. For example, given the rhombus RHOM, prove $\overline{RU} \cong \overline{OB}$.



Assessing for Understanding

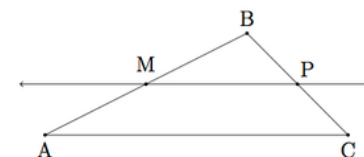
Students should demonstrate a solid understanding of lines and angles (Math 2), congruent triangles (Math 2), and properties of the centers of triangles (Math 3) and properties of parallelograms (Math 3). They should use their understanding of these properties, definitions and theorems to prove other geometric theorems and solve problems.

Example: Suppose ABC is a triangle. Let M be the midpoint of side AB and P the midpoint of side BC as pictured to the right:

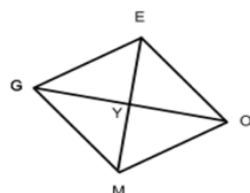
- Prove that line MP and line AC are parallel.
- Prove that $AC = 2MP$.

Adapted from Illustrative Math

(<https://www.illustrativemathematics.org/content-standards/tasks/1872>)



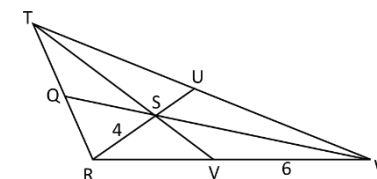
Example: Given $\overline{EY} \cong \overline{YM}$, $\overline{GY} \cong \overline{YO}$, and $\overline{EG} \cong \overline{EO}$. Prove GEOM is a rhombus.



Students should use properties of the centers of triangles to solve problems.

Example: S is the centroid of $\triangle RTW$; $RS = 4$, $VW = 6$ and $TV = 9$. Find the length of each segment:

- RV
- SU
- RU
- RW
- TS
- SV



Mastering the Standard

Comprehending the Standard

Finally, this standard should be connected to NC.M3.G-C.2 where students are understanding and applying theorems about circles.

There is not a specific list of theorems for students to know and use. The focus is not on specific theorems but on construction of logical arguments and the ability of students to explain their reasoning with two-dimensional figures.

Assessing for Understanding

Students should use theorems about parallelograms to solve problems.

Example: Given $MNPR$ is a parallelogram, \overline{MS} bisects $\angle RMN$ and \overline{NT} bisects $\angle MNP$

- Find the values of x and y .
- Describe the relationship between \overline{MS} and \overline{NT}

Example: In rectangle $ABCD$, $AC = 3x + 15$ and $BD = 4x - 5$. If AC and BD intersect at G , find the length of AG .

Students should be able to prove geometric theorems.

Example: Prove each of the following is true for an isosceles trapezoid.

- Base angles are congruent.
- Opposite angles are supplementary.
- Diagonals are congruent.

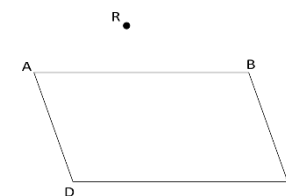
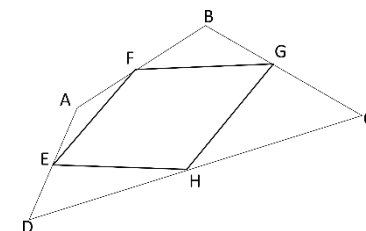
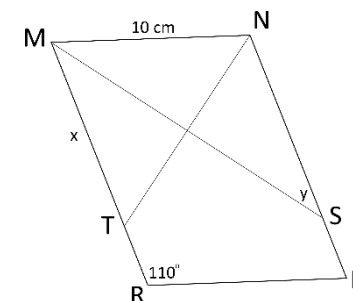
Example: For quadrilateral $ABCD$, points E , F , G and H are midpoints of their respective sides. Prove $EFGH$ is a parallelogram.

Students should be able to reason with two dimensional figures to solve problems.

Example: In figure $ABCD$, $AB \parallel CD$ and $AD \parallel BC$. Point R is in the same plane as $ABCD$. (Point R can be placed anywhere in the plane.)

Draw a straight line that passes through point R and divides $ABCD$ into two congruent parts. Justify your reasoning that the two parts are congruent.

Source: http://www.utdanacenter.org/k12mathbenchmarks/tasks/8_congruence.php



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Geometry – Circles

NC.M3.G-C.2

Understand and apply theorems about circles.

Understand and apply theorems about circles.

- Understand and apply theorems about relationships with angles and circles, including central, inscribed and circumscribed angles.
- Understand and apply theorems about relationships with line segments and circles including, radii, diameter, secants, tangents and chords.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> • Prove theorems about lines, angles, and segments for relationships in geometric figures (NC.M2.G-CO.9) • Use similarity to solve problems and to prove theorems about triangles (NC.M2.G-SRT.4)
Connections <ul style="list-style-type: none"> • Apply geometric concepts in modeling situations (NC.M3.G-MG.1)

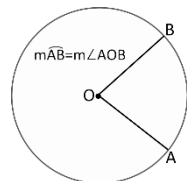
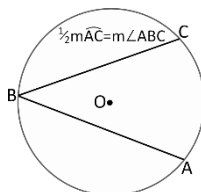
The Standards for Mathematical Practices
Connections <p>The following SMPs can be highlighted for this standard.</p> <p>1 – Make sense of problems and persevere in solving them</p> <p>3 – Construct viable arguments and critique the reasoning of others</p> <p>5 – Use appropriate tools strategically</p>
Disciplinary Literacy <p>New Vocabulary: <i>Circumscribe, inscribe, tangent</i></p>

Mastering the Standard

Comprehending the Standard

The following relationships with circles provide the foundation for reasoning with and applying theorems about circles:

- Relationships with angles and circles
 - **Central angle** is an angle formed by two intersecting radii such that its vertex is at the center of the circle; the measure of the angle is equal to the measure of the intersected arc
 - **Inscribed angle** is an angle with its vertex on the circle, formed by two intersecting chords; the measure of the angle is half the measure of the intersected arc



Assessing for Understanding

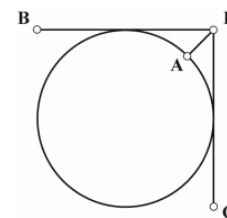
Students should have a strong command of the vocabulary: central angle, inscribed angle, circumscribed angle, tangent, arc (minor & major), secant, and chord.

Students demonstrate understanding when applying theorems about circles to explore other theorems.

- an angle inscribed in a semi-circle is a right angle.
- the opposite angles in an inscribed quadrilateral are supplementary.
- tangent lines drawn from a point outside a circle are equal in length.
- when two chords intersect at a point interior to a circle, the chords are divided proportionally.
- when two secants intersect at a point exterior to a circle, the lengths of the secants and the external parts are proportional.
- if two chords are equivalent then their minor arcs are congruent and conversely
- if two chords are equidistant from the center then they are congruent and conversely

Students demonstrate understanding when applying theorems about circles to solve problems with and without context.

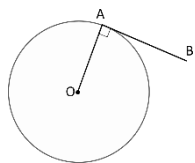
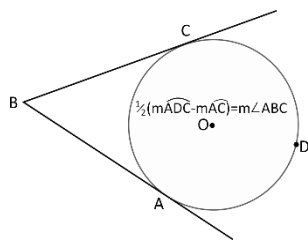
Example: A round table is pushed into a corner. The diameter of the table is 5 feet. Find the distance from the corner to the edge of the table



Mastering the Standard

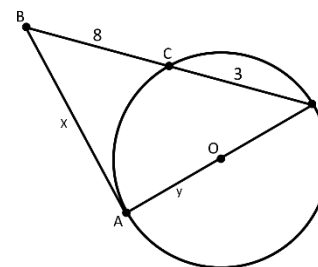
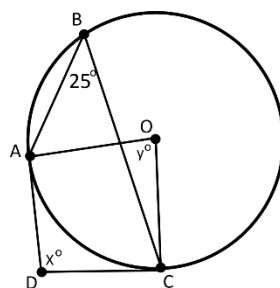
Comprehending the Standard

- **Circumscribed angle** is an angle formed by two tangents to a circle from the same point outside the circle; the measure of the angle is half the difference of the intercepted arcs
- Relationships with line segments and circles:
 - **Tangent line** intersects the circle exactly once at the point of tangency; the tangent line is perpendicular to the radius at the point of tangency



Assessing for Understanding

Example: Find the value of x and y .



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Geometry – Circles

NC.M3.G-C.5

Understand and apply theorems about circles.

Using similarity, demonstrate that the length of an arc, s , for a given central angle is proportional to the radius, r , of the circle. Define radian measure of the central angle as the ratio of the length of the arc to the radius of the circle, s/r . Find arc lengths and areas of sectors of circles.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Know the formulas for the area and circumference of a circle and use them to solve problems (7.G.4) Verify the properties of dilations with given center and scale factor (NC.M2.G-SRT.1)
Connections
<ul style="list-style-type: none"> Understand radian measure as domain for trigonometric functions (NC.M3.G-TF.1) Apply geometric concepts in modeling situations (NC.M3.G-MG.1)

The Standards for Mathematical Practices
Connections
<p>The following SMPs can be highlighted for this standard.</p> <p>3 – Construct viable arguments and critique the reasoning of others</p>
Disciplinary Literacy

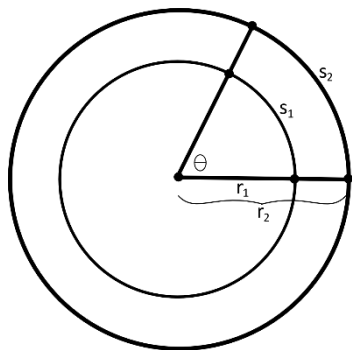
Mastering the Standard

Comprehending the Standard

Circles are similar figures; thus, any two arcs, subtended by the same central angle, will be proportional.

Since corresponding parts of similar figures are proportional then $\frac{r_1}{r_2} = \frac{s_1}{s_2}$ which can also be written

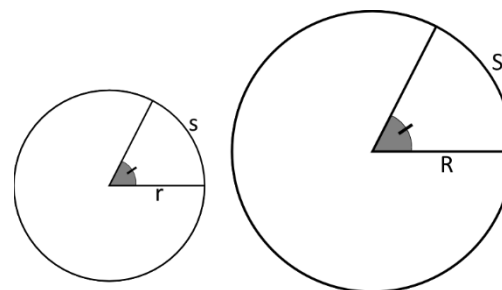
as $s_1 = \left(\frac{s_2}{r_2}\right)r_1$. The structure of the equation reveals that the length of the arc is directly proportional to the radius and $\frac{s_2}{r_2}$ is the constant of proportionality.



Furthermore, a radian is defined as the ratio of the length of the arc to the radius of the circle, $\frac{s}{r}$, so the constant of proportionality is the radian measure of the angle.

Assessing for Understanding

Students demonstrate an understanding of the proportional relationship between the length of an arc and the radius of the circle by explaining how the following two diagrams could be used to prove that $s = kr$ where $k = \frac{s}{r}$ which is the radian measure of the central angle.



Students should use the definition of a radian to answer and solve problems.

Example: Explain why there are 2π radians in a circle. *Students explain that the radian measure is the ratio of the total length of the circle, $2\pi r$, to the radius r . Thus $\frac{2\pi r}{r} = 2\pi$ radians.*

Example: The length of an arc is 18 cm and the radius of the circle is 6cm. What is the radian measure of the central angle?

Example: A central angle measures 4.5 radians and has an arc length of 35 inches. What is the radius of the circle?

Mastering the Standard

Comprehending the Standard

Using the reasoning presented, the arc length, s , can be calculated using the formula $s = \theta r$ where θ is the radian measure and r is the radius of the circle.

The length of an arc subtended by a central angle can also be expressed as a fraction of the circumference. Given the central angle θ in degrees, the arc length is $s = \frac{\theta}{360^\circ}(2\pi r)$. Given the central angle θ in radians, the arc length is $s = \frac{\theta}{2\pi}(2\pi r) = \theta r$.

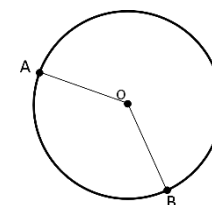
Similarly, the area of a sector can be expressed as a fraction of the area of the circle. Given the central angle in degrees and the radius r , the area of a sector is $\frac{\theta}{360^\circ}(\pi r^2)$. Given the central angle in radians and the radius r , the area of the sector is $\frac{\theta}{2\pi}(\pi r^2) = \frac{\theta}{2}r^2 = \frac{sr}{2}$ where s is the arc length.

Assessing for Understanding

Students should be able to calculate arc lengths and areas of sectors of circles.

Example: Given that $m\angle AOB = \frac{2\pi}{3}$ radians and the radius is 18 cm, what is the length of \widehat{AB} ?

Example: Find the area of a sector with an arc length of 40 cm and a radius of 12 cm.



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Geometry – Expressing Geometric Properties with Equations

NC.M3.G-GPE.1

Translate between the geometric description and the equation for a conic section.

Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

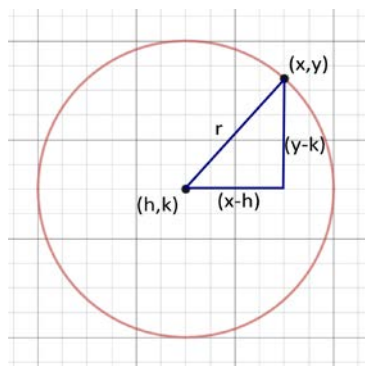
Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Apply the Pythagorean Theorem to find the distance between two points (8.G.8) Write an equivalent form of a quadratic expression by completing the square (NC.M2.A-SSE.3)
Connections <ul style="list-style-type: none"> Work with conic sections (4th level course)

The Standards for Mathematical Practices
Connections <p>The following SMPs can be highlighted for this standard.</p> <p>2 – Reason abstractly and quantitatively</p>
Disciplinary Literacy

Mastering the Standard

Comprehending the Standard

Students derive the standard equation of a circle by reasoning with circles on the coordinate plane. Given a center (h, k) and a radius r , students determine that the horizontal distance from the center to a point (x, y) on the circle can be expressed by $(x - h)$. Likewise, the vertical distance from the center to the point can be expressed by $(y - k)$. These distances can be modeled by a vertical and horizontal line segment. The radius can be modeled by a line segment connecting the center to the point. A right triangle is formed and the Pythagorean Theorem can be applied to derive $(x - h)^2 + (y - k)^2 = r^2$.



For a circle equation in general form $x^2 + y^2 + cx + dx + e = 0$, students will use the process of completing the square to rewrite and identify the center and radius of the circle. (The process of completing the square is in Math 2 NC.M2.A-SSE.3.)

Assessing for Understanding

Students demonstrate an understanding of the equation of a circle by writing the equation using the center and radius.

Example: Write the equation of a circle that is centered at $(-1, 3)$ with a radius of 5 units.

Example: Using the whole numbers 1 – 9 as many times as you like, make the biggest circle by filling in the blanks below:

$$\square x^2 + \square y^2 = \square$$

Source: <http://www.openmiddle.com/make-the-biggest-circle/>

Example: Write an equation for a circle given that the endpoints of the diameter are $(-2, 7)$ and $(4, -8)$

Example: How many points with two integer coordinates are 5 units away from $(-2, 3)$?

Source: <http://www.openmiddle.com/equidistant-points/>

Students can rewrite the equation of a circle to identify the center and radius.

Example: Find the center and radius of the circle $4x^2 + 4y^2 - 4x + 2y - 1 = 0$.

Instructional Resources

Tasks	Additional Resources
Explaining the Equation of a Circle (Illustrative Mathematics) Sorting the Equations of a Circle 1 (MathShell) Sorting the Equations of a Circle 2 (MathShell)	

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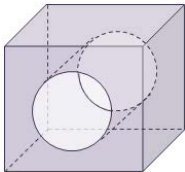
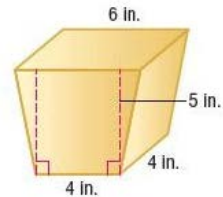
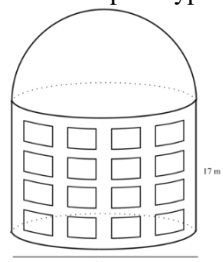
Geometry – Geometric Measurement & Dimension

NC.M3.G-GMD.3

Explain volume formulas and use them to solve problems.

Use the volume formulas for prisms, cylinders, pyramids, cones, and spheres to solve problems.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Know and use formulas for volumes of cones, cylinders, and spheres (8.G.9) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 1 – Make sense of problems and persevere in solving them
Connections <ul style="list-style-type: none"> Solve for a quantity of interest in formulas (NC.M1.A-CED.4) Apply geometric concepts in modeling situations (NC.M3.G-MG.1) 	Disciplinary Literacy

Mastering the Standard	
Comprehending the Standard <p>This standard focuses on volume and the use of volume formulas to solve problems. The figures may be a single shape or a composite of shapes.</p> <p>Formulas should be provided as the figures are more complex and the focus is on the modeling and solving problems.</p>	Assessing for Understanding <p>Students should be able to identify the 3-D figures (prisms, cylinders, pyramids, cones and spheres) and the measurements needed to calculate the volume.</p> <div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="width: 45%;">  <p>Example: A toy manufacture has designed a new piece for use in building models. It is a cube with side length 7 mm and it has a 3 mm diameter circular hole cut through the middle. The manufacture wants 1,000,000 prototypes. If the plastic used to create the piece costs \$270 per cubic meter, how much will the prototypes cost?</p> </div> <div style="width: 45%;">  <p>Example: A carryout container is shown. The bottom base is a 4-inch square and the top base is a 4-inch by 6-inch rectangle. The height of the container is 5 inches. Find the volume of food that it holds.</p> </div> </div> <div style="margin-top: 20px;">  <p>Example: The Southern African Large Telescope (SALT) is housed in a cylindrical building with a domed roof in the shape of a hemisphere. The height of the building wall is 17 m and the diameter is 26 m. To program the ventilation system for heat, air conditioning, and dehumidifying, the engineers need the amount of air in the building. What is the volume of air in the building?</p> </div>

Instructional Resources	
Tasks Cylinders (OpenMiddle.com) Calculating Volumes of Compound Objects	Additional Resources

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Geometry – Geometric Measurement & Dimension

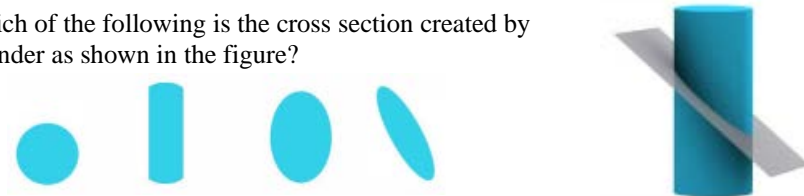
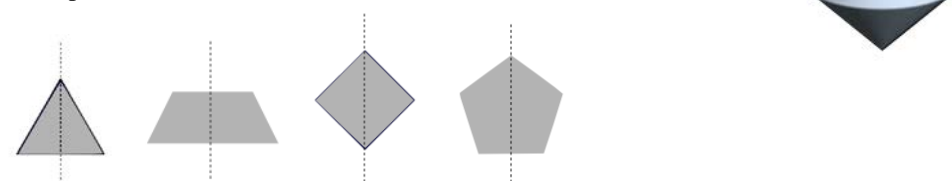
NC.M3.G-GMD.4

Visualize relationships between two-dimensional and three-dimensional objects.

Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

Concepts and Skills
Pre-requisite
<ul style="list-style-type: none"> Describe 2-D cross-sections of rectangular prisms and pyramids (7.G.3)
Connections
<ul style="list-style-type: none"> Apply geometric concepts in modeling situations (NC.M3.G-MG.1)

The Standards for Mathematical Practices
Connections
<i>The following SMPs can be highlighted for this standard.</i> 2 – Reason abstractly and quantitatively 4 – Model with mathematics
Disciplinary Literacy

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>This standard has two parts.</p> <p>The first part is to identify the two-dimensional cross sections of three-dimensional objects.</p> <p>Consider having students work with manipulatives such as play-dough and floss to make slices of three-dimensional shapes. Also, the <i>Cross Section Flyer</i> at http://www.shodor.org/interactivate/activities/CrossSectionFlyer/ can be used to allow students to predict and verify the cross section of different three-dimensional objects.</p> <p>The second part is identifying three-dimensional objects generated by rotations of two-dimensional objects. There are a few interactive websites that students can use to explore.</p> <ul style="list-style-type: none"> 3D Transmographer http://www.shodor.org/interactivate/activities/3DTransmographer/ Interactive Tool: Stacker http://www.scootle.edu.au/ec/viewing/L588/index.html Interactive Tool: Replicator http://www.scootle.edu.au/ec/viewing/L1059/index.html 	<p>Students identify shapes of two-dimensional cross-sections of three-dimensional objects.</p> <p>Example: Draw a figure that has the same cross section as a sphere.</p> <p>Example: Which of the following is the cross section created by slicing the cylinder as shown in the figure?</p>  <p>Students identify three-dimensional objects generated by rotations of two-dimensional objects.</p> <p>Example: The shape at the right was created by rotating a two dimensional shape about an axis. Which of the following would create this shape?</p> 

Instructional Resources	
Tasks	Additional Resources
Representing 3D objects in 2D	

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Geometry – Modeling with Geometry

NC.M3.G-MG.1

Apply geometric concepts in modeling situations.

Apply geometric concepts in modeling situations

- Use geometric and algebraic concepts to solve problems in modeling situations:
- Use geometric shapes, their measures, and their properties, to model real-life objects.
- Use geometric formulas and algebraic functions to model relationships.
- Apply concepts of density based on area and volume.
- Apply geometric concepts to solve design and optimization problems.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> • Solve real world problems involving area, volume, and surface area (7.G.6) • Use volume formulas to solve problems (NC.M3.G-GMD.3)
Connections <ul style="list-style-type: none"> • Apply properties, definitions, and theorems of 2-D figures to solve problems (NC.M3.G-CO.14) • Understand and apply theorems about circles (NC.M3.G-C.2) • Find arc lengths and areas of sectors of circles (NC.M3.G-C.5) • Identify 2-D cross sections; identify 3-D objects (NC.M3.G-GMD.4)

The Standards for Mathematical Practices
Connections <i>The following SMPs can be highlighted for this standard.</i> 1 – Make sense of problems and persevere in solving them 4 – Model with mathematics
Disciplinary Literacy

Mastering the Standard

Comprehending the Standard	Assessing for Understanding
<p>For this standard, students should engage in problems that are more complex than those studied in previous grades. The standard combines geometric and algebraic concepts and focuses on four primary areas:</p> <ol style="list-style-type: none"> i. model real-world three-dimensional figures, ii. model relationships, iii. determine density based on area or volume, and iv. solve design and optimization problems. <p>When students model real-world three dimensional figures they must recognize the plane shapes that comprise the figure. They must be flexible in constructing and deconstructing the shapes. Students also need to be able to identify the measures associated with the figure such as circumference, area, perimeter, and volume.</p> <p>Students use formulas and algebraic functions when modeling relationships. This may include examining how the one measurement changes as another changes.</p> <p><i>How does the volume of a cylinder change as the radius changes?</i> <i>How does the surface area of a prism change as the height changes?</i></p>	<p>Use geometric and algebraic concepts to solve problems in modeling situations.</p> <p>Example: Janine is planning on creating a water-based centerpiece for each of the 30 tables at her wedding reception. She has already purchased a cylindrical vase for each table.</p> <ul style="list-style-type: none"> • The radius of the vases is 6 cm and the height is 28 cm. • She intends to fill them half way with water and then add a variety of colored marbles until the waterline is approximately three-quarters of the way up the cylinder. • She can buy bags of 100 marbles in 2 different sizes, with radii of 9mm or 12 mm. A bag of 9 mm marbles costs \$3, and a bag of 12 mm marbles costs \$4. <ol style="list-style-type: none"> a. If Janine only bought 9 mm marbles how much would she spend on marbles for the whole reception? What if Janine only bought 12 mm marbles? (Note: $1 \text{ cm}^3 = 1 \text{ mL}$) b. Janine wants to spend at most d dollars on marbles. Write a system of equalities and/or inequalities that she can use to determine how many marbles of each type she can buy. c. Based on your answer to part b. How many bags of each size marble should Janine buy if she has \$180 and wants to buy as many small marbles as possible?

Mastering the Standard

Comprehending the Standard

The concept of density based on area and volume is to calculate the mass per unit.

Examples for area density are:

<i>Description</i>	<i>Unit of Measure</i>
<i>Data Storage</i>	Gigabytes per square inch
<i>Thickness of Paper</i>	Grams per square meter
<i>Bone density</i>	Grams per square centimeter
<i>Body Mass Index</i>	Kilograms per square meter
<i>Population</i>	People per square mile

Examples for volume density are:

<i>Description</i>	<i>Unit of Measure</i>
<i>Solids</i>	Grams per cubic centimeter
<i>Liquids</i>	Grams per milliliter (1 mL = 1 cubic cm)

Design problems include designing an object to satisfy physical constraints. Optimization problems may maximize or minimize depending on the context.

Students recognize situations that require relating two- and three- dimensional objects. They estimate measures (circumference, area, perimeter, volume) of real-world objects using comparable geometric shapes or three-dimensional objects. Students apply the properties of geometric figures to comparable real-world objects (e.g., The spokes of a wheel of a bicycle are equal lengths because they represent the radii of a circle).

Assessing for Understanding

Example: A gas company wants to determine what shape truck will hold the most gas to transport to the gas stations. The truck with a 58-foot bed can hold either a cylinder of diameter x ft. or a rectangular prism with a width and height of x ft. The have found out that a new, more advanced truck can increase the length of the diameter, width, and height by 4. Write a function to represent the volume of each container for the new truck. Which one can hold the most gas?

Geometric shapes, their measures, and their properties to model real-life objects

Example: Describe each of the following as a simple geometric shape or combination of shapes. Illustrate with a sketch and label dimensions important to describing the shape.

- Soup can label
- A bale of hay
- Paperclip
- Strawberry

Use geometric formulas and algebraic functions to model relationships.

Example: A grain silo has the shape of a right circular cylinder topped by a hemisphere. If the silo is to have a capacity of 614π cubic feet, find the radius and height of the silo that requires the least amount of material to construct.

Density based problems

Example: A King Size waterbed has the following dimensions 72 in. x 84 in. x 9.5in. It takes 240.7 gallons of water to fill it, which would weigh 2071 pounds. What is the weight of a cubic foot of water?

Example: Wichita, Kansas has 344,234 people within 165.9 square miles. What is Wichita's population density?

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Statistics & Probability

A statistical process is a problem-solving process consisting of four steps:

1. Formulating a statistical question that anticipates variability and can be answered by data.
2. Designing and implementing a plan that collects appropriate data.
3. Analyzing the data by graphical and/or numerical methods.
4. Interpreting the analysis in the context of the original question.

NC Math 1	NC Math 2	NC Math 3
Focus on analysis of univariate and bivariate data <ul style="list-style-type: none"> • Use of technology to represent, analyze and interpret data • Shape, center and spread of univariate numerical data • Scatter plots of bivariate data • Linear and exponential regression • Interpreting linear models in context. 	Focus on probability <ul style="list-style-type: none"> • Categorical data and two-way tables • Understanding and application of the Addition and Multiplication Rules of Probability • Conditional Probabilities • Independent Events • Experimental vs. theoretical probability 	Focus on the use of sample data to represent a population <ul style="list-style-type: none"> • Random sampling • Simulation as it relates to sampling and randomization • Sample statistics • Introduction to inference
A Progression of Learning		
<ul style="list-style-type: none"> • A continuation of the work from middle grades mathematics on summarizing and describing quantitative data distributions of univariate (6th grade) and bivariate (8th grade) data. 	<ul style="list-style-type: none"> • A continuation of the work from 7th grade where students are introduced to the concept of probability models, chance processes and sample space; and 8th grade where students create and interpret relative frequency tables. • The work of MS probability is extended to develop understanding of conditional probability, independence and rules of probability to determine probabilities of compound events. 	<ul style="list-style-type: none"> • Bringing it all back together • Sampling and variability • Collecting unbiased samples • Decision making based on analysis of data

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Statistics & Probability – Making Inference and Justifying Conclusions

NC.M3.S-IC.1

Understand and evaluate random processes underlying statistical experiments.

Understand the process of making inferences about a population based on a random sample from that population.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Use data from a random sample to draw inferences about a population (7.SP.2)
Connections <ul style="list-style-type: none"> Recognize the purpose and differences between samples and studies and how randomization is used (NC.M3.S-IC.3) Use simulation estimate a population mean or proportion (NC.M3.S-IC.4) Use simulation to determine whether observed differences between samples indicate the two populations are distinct (NC.M3.S-IC.5)

The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>6 – Attend to precision</p>
Disciplinary Literacy <p><i>New Vocabulary: sample, population, random sample, inferential statistics</i></p>

Mastering the Standard	
Comprehending the Standard <p>The statistical process includes four essential steps:</p> <ol style="list-style-type: none"> Formulate a question that can be answered with data. Design and use a plan to collect data. Analyze the data with appropriate methods. Interpret results and draw valid conclusions. <p>An essential understanding about the data collection step is that random selection can produce samples that represent the overall population. This allows for the generalization from the sample to the larger population in the last step of the process.</p> <p><i>A population</i> consists of everything or everyone being studied in an inference procedure. It is rare to be able to perform a census of every individual member of the population. Due to constraints of resources it is nearly impossible to perform a measurement on every subject in a population.</p> <p><i>A random sample</i> is a sample composed of selecting from the population using a chance mechanism. Often referred to as a simple random sample.</p> <p><i>Inferential statistics</i> considers a subset of the population. This subset is called a statistical sample</p>	Assessing for Understanding <p>Students demonstrate an understanding of the different kinds of sampling methods.</p> <p>Example: From a class containing 12 girls and 10 boys, three students are to be selected to serve on a school advisory panel. Here are four different methods of making the selection.</p> <ol style="list-style-type: none"> Select the first three names on the class roll. Select the first three students who volunteer. Place the names of the 22 students in a hat, mix them thoroughly, and select three names from the mix. Select the first three students who show up for class tomorrow. <p>Which is the best sampling method, among these four, if you want the school panel to represent a fair and representative view of the opinions of your class? Explain the weaknesses of the three you did not select as the best.</p> <p>Students recognize the need for random selection, describe a method for selecting a random sample from a given population, and explain why random assignment to treatments is important in the design of a statistical experiment.</p> <p>Example: A department store manager wants to know which of two advertisements is more effective in increasing sales among people who have a credit card with the store. A sample of 100 people will be selected from the 5,300 people who have a credit card with the store. Each person in the sample will be called and read one of the two advertisements. It will then be determined if the credit card holder makes a purchase at the department store within two weeks of receiving the call.</p> <ol style="list-style-type: none"> Describe the method you would use to determine which credit card holders should be included in the sample. Provide enough detail so that someone else would be able to carry out your method. For each person in the sample, the department store manager will flip a coin. If it lands heads up, advertisement A will be read. If it lands tails up, advertisement B will be read. Why would the manager use this method to decide which advertisement is read to each person? <p style="text-align: right;">Source: https://locus.statisticeducation.org/</p>

Mastering the Standard	
Comprehending the Standard often including members of a population selected in a random process. The measurements of the individuals in the sample tell us about corresponding measurements in the population.	Assessing for Understanding

Instructional Resources	
Tasks	Additional Resources

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Statistics & Probability – Making Inference and Justifying Conclusions

NC.M3.S-IC.3

Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Recognize the purposes of and differences between sample surveys, experiments, and observational studies and understand how randomization should be used in each.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Understand the process of making inferences (NC.M3.S-IC.1)
Connections <ul style="list-style-type: none"> Use simulation estimate a population mean or proportion (NC.M3.S-IC.4) Use simulation to determine whether observed differences between samples indicate the two populations are distinct (NC.M3.S-IC.5)

The Standards for Mathematical Practices
Connections <p>The following SMPs can be highlighted for this standard.</p> <p>4 – Model with mathematics</p>
Disciplinary Literacy <p>New Vocabulary: <i>Observational study, simulation, sample, population, random sample, inferential statistics</i></p>

Mastering the Standard	
Comprehending the Standard <p>Students understand the different methods of data collection, specifically the difference between an observational study and a controlled experiment and know the appropriate use for each.</p> <ul style="list-style-type: none"> <i>Observational study</i> – a researcher collects information about a population by measuring a variable of interest but does not impose a treatment on the subjects. (i.e. examining the health effects of smoking) <i>Experiment</i> – an investigator imposes a change or treatments on one or more group(s), often called treatment group(s). A comparative experiment is where a control group is given a placebo to compare the reaction(s) between the treatment group(s) and the control group. 	Assessing for Understanding <p>Students should be able to distinguish between the different methods.</p> <p>Example: A student wants to determine the most liked professor at her college. Which type of study would be the most practical to obtain this information?</p> <ol style="list-style-type: none"> simulation experiment survey observation <p style="text-align: right;">Source: NC Measure of Student Learning CC Math III Spring 2013</p> <p>Students understand the role that randomization plays in eliminating bias from collected data.</p> <p>Example: Students in a high school mathematics class decided that their term project would be a study of the strictness of the parents or guardians of students in the school. Their goal was to estimate the proportion of students in the school who thought of their parents or guardians as “strict”. They do not have time to interview all 1000 students in the school, so they plan to obtain data from a sample of students.</p> <ol style="list-style-type: none"> Describe the parameter of interest and a statistic the students could use to estimate the parameter. Is the best design for this study a sample survey, an experiment, or an observational study? Explain your reasoning. The students quickly realized that, as there is no definition of “strict”, they could not simply ask a student, “Are your parents or guardians strict?” Write three questions that could provide objective data related to strictness. Describe an appropriate method for obtaining a sample of 100 students, based on your answer in part (a) above.

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Statistics & Probability – Making Inference and Justifying Conclusions

NC.M3.S-IC.4

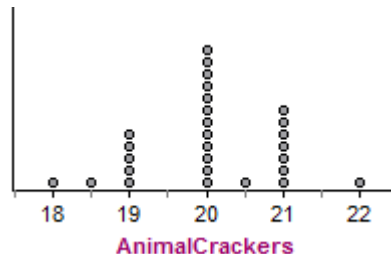
Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Use simulation to understand how samples can be used to estimate a population mean or proportion and how to determine a margin of error for the estimate.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Design and use simulation to generate frequencies for compound events (7.SP.8c) Understand the process of making inferences (NC.M3.S-IC.1)
Connections <ul style="list-style-type: none"> Recognize the purpose and differences between samples and studies and how randomization is used (NC.M3.S-IC.3) Use simulation to determine whether observed differences between samples indicate the two populations are distinct (NC.M3.S-IC.5)

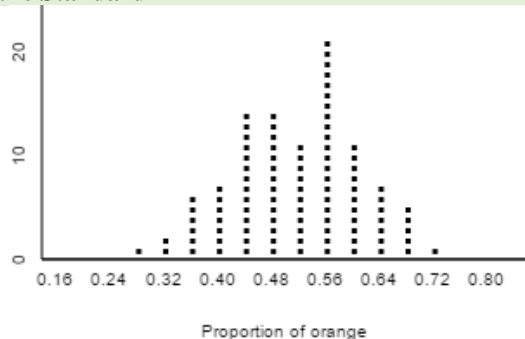
The Standards for Mathematical Practices
Connections <p><i>The following SMPs can be highlighted for this standard.</i></p> <p>4 – Model with mathematics</p> <p>6 – Attend to precision</p>
Disciplinary Literacy <p><i>New Vocabulary: simulation, sample, population, margin of error, parameter</i></p>

Mastering the Standard

Comprehending the Standard	Assessing for Understanding												
<p>This standard has two parts:</p> <ol style="list-style-type: none"> Use simulation to understand how samples can be used to estimate a population mean or proportion Use simulation to determine a margin of error for the estimate <p>Simulations may use physical manipulatives: dice, cards, beads, decks of playing cards. If available, simulations can be completed using technology. In either situation, students should have a clear understanding of how the simulation models the situation.</p> <p>For estimating a population mean or proportion, students understand that a sample only provides an <i>estimate</i> of the population parameter. With repeated sampling, the estimates vary, and a sampling distribution can be created to model the variation.</p> <p>Consider trying to determine the proportion of orange candies in Reese’s Pieces. After taking a sample of 25 pieces, the proportion of orange is 0.40. Another sample has a proportion of orange as 0.60. By taking 100 random samples and computing the proportion of orange for each one a sampling distribution can be made.</p>	<p>Students should use a simulation to estimate a population mean or proportion and determine a margin of error for that estimate.</p> <p>Example: The label on a Barnum’s Animal Cracker box claims that there are 2 servings per box and a serving size is 8 crackers. The graph displays the number of animal crackers found in a sample of 28 boxes. Use the data from the 28 samples to estimate the average number of crackers in a box with a margin of error. Explain your reasoning or show your work.</p> <div style="text-align: center;">  <table border="1" style="margin: 10px auto;"> <caption>Data from Animal Cracker Dot Plot</caption> <thead> <tr> <th>Number of Crackers</th> <th>Frequency (Number of Boxes)</th> </tr> </thead> <tbody> <tr> <td>18</td> <td>1</td> </tr> <tr> <td>19</td> <td>4</td> </tr> <tr> <td>20</td> <td>10</td> </tr> <tr> <td>21</td> <td>6</td> </tr> <tr> <td>22</td> <td>1</td> </tr> </tbody> </table> </div>	Number of Crackers	Frequency (Number of Boxes)	18	1	19	4	20	10	21	6	22	1
Number of Crackers	Frequency (Number of Boxes)												
18	1												
19	4												
20	10												
21	6												
22	1												

Mastering the Standard

Comprehending the Standard



Using the sampling distribution, students can estimate a population proportion using the mean of the distribution (0.51).

Simulation for Reese's Pieces at

<http://www.rossmanchance.com/applets/OneProp/OneProp.htm?candy=1>

Students should understand that the margin of error is the maximum **range that reflects the accuracy** in prediction. In other words, it is the *most* that a value of a sample statistic is likely to differ from the actual value of the population parameter.

One informal way of developing a margin of error from a simulation is to **simulate using repeated sampling; then examining the sampling distribution to find the largest range from the mean of the distribution that is less than 100% of the data (90-95%). Start at the mean and use the scale to widen the interval until you capture *most* of the data.**

Taking larger sample sizes should decrease the margin of error.

Changing the sample size to 50 gives a margin of error of 0.15.

Margin of error can be computed by formula; however, this standard is intended to engage students in using simulations to estimate. Note that confidence intervals are beyond what is intended in the standard. Students should have an idea of what margin of error is and how it is interpreted, which can lead informally to the idea of an interval estimate.

Assessing for Understanding

Instructional Resources

Tasks

[Scratch 'N Win Blues](#) (Illustrative Mathematics)

[Margin of Error for Estimating a Population Mean](#) (Illustrative Mathematics)

Additional Resources

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Statistics & Probability – Making Inference and Justifying Conclusions

NC.M3.S-IC.5

Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Use simulation to determine whether observed differences between samples from two distinct populations indicate that the two populations are actually different in terms of a parameter of interest.

Concepts and Skills
Pre-requisite <ul style="list-style-type: none"> Design and use simulation to generate frequencies for compound events (7.SP.8c) Understand the process of making inferences (NC.M3.S-IC.1)
Connections <ul style="list-style-type: none"> Recognize the purpose and differences between samples and studies and how randomization is used (NC.M3.S-IC.3) Use simulation estimate a population mean or proportion (NC.M3.S-IC.4)

The Standards for Mathematical Practices
Connections <i>The following SMPs can be highlighted for this standard.</i> 4 – Model with mathematics 6 – Attend to precision
Disciplinary Literacy New Vocabulary: simulation, sample, population, parameter

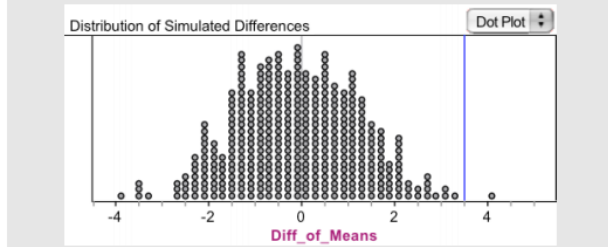
Mastering the Standard																							
Comprehending the Standard	Assessing for Understanding																						
<p>The statistical process includes four essential steps:</p> <ol style="list-style-type: none">1. Formulate a question that can be answered with data.2. Design and use a plan to collect data.3. Analyze the data with appropriate methods.4. Interpret results and draw valid conclusions. <p>This standard addresses parts 3 and 4 of this process. Once data is collected from an experiment, it is necessary to determine if there are differences between the two treatment groups. If so, are the differences due to the treatment or due to variation within the population?</p> <p>Select a sample statistic to compare. For example, the mean of each sample.</p> <p>Consider the experiment where twenty male students were randomly assigned to one of two treatment groups of 10 students each, one group receiving 200 milligrams of caffeine and the other group no caffeine.</p> <p>The parameter of interest is the number of finger taps per minute. The sample statistics showed that the mean of the 200 mg group was 3.5 taps more than the 0 mg group. Thus, an observed difference.</p> <p>Use simulation to determine if the observed difference is due to the caffeine.</p>	<p>Students should demonstrate an understanding of the process by</p> <ul style="list-style-type: none">• identifying the parameter of interest,• select and calculate sample statistics,• calculate the difference between the sample statistic,• set up and complete a simulation re-randomizing the groups,• and compare the actual difference to the simulated differences <p>Example: Sal purchased two types of plant fertilizer and conducted an experiment to see which fertilizer would be best to use in his greenhouse. He planted 20 seedlings and used Fertilizer A on ten of them and Fertilizer B on the other ten. He measured the height of each plant after two weeks. Use the data below to determine which fertilizer Sal should use.</p> <table><tr><td>Fertilizer A</td><td>23.4</td><td>30.1</td><td>28.5</td><td>26.3</td><td>32.0</td><td>29.6</td><td>26.8</td><td>25.2</td><td>27.5</td><td>30.8</td></tr><tr><td>Fertilizer B</td><td>19.8</td><td>25.7</td><td>29.0</td><td>23.2</td><td>27.8</td><td>31.1</td><td>26.5</td><td>24.7</td><td>21.3</td><td>25.6</td></tr></table> <ol style="list-style-type: none">a. Use the data to generate simulated treatment results by randomly selecting ten plant heights from the twenty plant heights listed.b. Calculate the average plant height for each treatment of ten plants.c. Find the difference between consecutive pairs of treatment averages and compare. Does your simulated data provide evidence that the average plant heights using Fertilizer A and Fertilizer B is significant?	Fertilizer A	23.4	30.1	28.5	26.3	32.0	29.6	26.8	25.2	27.5	30.8	Fertilizer B	19.8	25.7	29.0	23.2	27.8	31.1	26.5	24.7	21.3	25.6
Fertilizer A	23.4	30.1	28.5	26.3	32.0	29.6	26.8	25.2	27.5	30.8													
Fertilizer B	19.8	25.7	29.0	23.2	27.8	31.1	26.5	24.7	21.3	25.6													

Mastering the Standard

Comprehending the Standard

Is it possible that the 3.5 taps was due to randomization and not caffeine? In order to find out, re-randomize the participants and calculate the difference in means. Simulate this and create a distribution of the results.

Differences in re-randomized means for finger tapping data



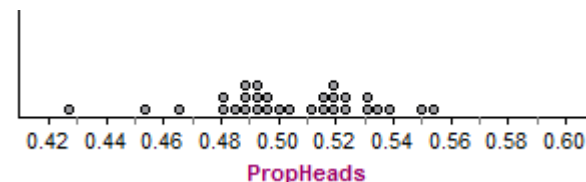
The results of the simulation shows that the difference of 3.5 is equaled or exceeded only once out of 400 trials this providing strong evidence that the caffeine is the cause of the increased tapping.

Source: http://commoncoretools.me/wp-content/uploads/2012/06/ccss_progression_sp_hs_2012_04_21_bis.pdf

Assessing for Understanding

Example: “Are Starbucks customers more likely to be female?” To answer the question, students decide to randomly select 30-minute increments of time throughout the week and have an observer record the gender of every tenth customer who enters the Starbucks store. At the end of the week, they had collected data on 260 customers, 154 females and 106 males. This data seems to suggest more females visited Starbucks during this time than males.

To determine if these results are statistically significant, students investigated if they could get this proportion of females just by chance if the population of customers is truly 50% females and 50% males. Students simulated samples of 260 customers that are 50-50 females to males by flipping a coin 260 then recording the proportion of heads to represent the number of women in a random sample of 260 customers (e.g., 0.50 means that 130 of the 260 flips were heads). Their results are displayed in the graph at the right.



Use the distribution to determine if the class’s data is statistically significant enough to conclude that Starbucks customers are more likely to be female.

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Statistics & Probability – Making Inference and Justifying Conclusions

NC.M3.S-IC.6

Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Evaluate articles and websites that report data by identifying the source of the data, the design of the study, and the way the data are graphically displayed.

Concepts and Skills	The Standards for Mathematical Practices
Pre-requisite <ul style="list-style-type: none"> Use appropriate statistics to compare center and spread of two or more data sets and interpret differences in context (NC.M1.S-ID.2) Recognize the purpose and differences between samples and studies and how randomization is used (NC.M3.S-IC.3) 	Connections <i>The following SMPs can be highlighted for this standard.</i> 4 – Model with mathematics 6 – Attend to precision
Connections	Disciplinary Literacy

Mastering the Standard	
Comprehending the Standard	Assessing for Understanding
<p>The statistical process includes four essential steps:</p> <ol style="list-style-type: none"> Formulate a question that can be answered with data. Design and use a plan to collect data. Analyze the data with appropriate methods. Interpret results and draw valid conclusions. <p>When students are presented with information supported by data, they should critically examine the source of the data, the design of the study and the graphs to determine the validity of the article or website.</p> <p>Students should recognize how graphs and data can be distorted to support different points of view. Students should use spreadsheet tables and graphs or graphing technology to recognize and analyze distortions in data displays.</p> <p>This standard connects to NC.M3.S-IC.1, 3, 4, & 5.</p>	<p>Students critically evaluate the source of the data, the design of the study, and the graphical displays.</p> <p>Example: Read the article below from NPR.org then answer the following questions.</p> <p style="text-align: center;">Kids and Screen Time: What Does the Research Say? By Juana Summers August 28, 2014</p> <p>Kids are spending more time than ever in front of screens, and it may be inhibiting their ability to recognize emotions, according to new research out of the University of California, Los Angeles.</p> <p>The study, published in the journal <i>Computers in Human Behavior</i>, found that sixth-graders who went five days without exposure to technology were significantly better at reading human emotions than kids who had regular access to phones, televisions and computers.</p> <p>The UCLA researchers studied two groups of sixth-graders from a Southern California public school. One group was sent to the Pali Institute, an outdoor education camp in Running Springs, Calif., where the kids had no access to electronic devices. For the other group, it was life as usual.</p> <p>At the beginning and end of the five-day study period, both groups of kids were shown images of nearly 50 faces and asked to identify the feelings being modeled. Researchers found that the students who went to camp scored significantly higher when it came to reading facial emotions or other nonverbal cues than the students who continued to have access to their media devices.</p>

Mastering the Standard

Comprehending the Standard

Assessing for Understanding

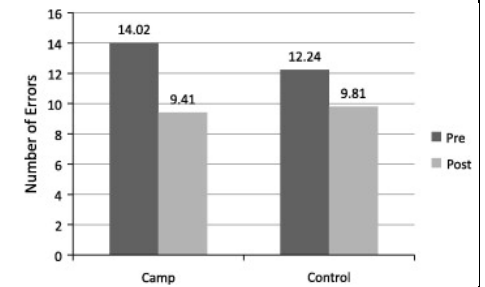
"We were pleased to get an effect after five days," says Patricia Greenfield, a senior author of the study and a distinguished professor of psychology at UCLA. "We found that the kids who had been to camp without any screens but with lots of those opportunities and necessities for interacting with other people in person improved significantly more."

If the study were to be expanded, Greenfield says, she'd like to test the students at camp a third time — when they've been back at home with smartphones and tablets in their hands for five days.

"It might mean they would lose those skills if they weren't maintaining continual face-to-face interaction," she says.

- a. What is the source of the data?
- b. Describe the design of the study.

After analyzing the graph, evaluate the claim that the “kids who had been to camp ... improved significantly more.”



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